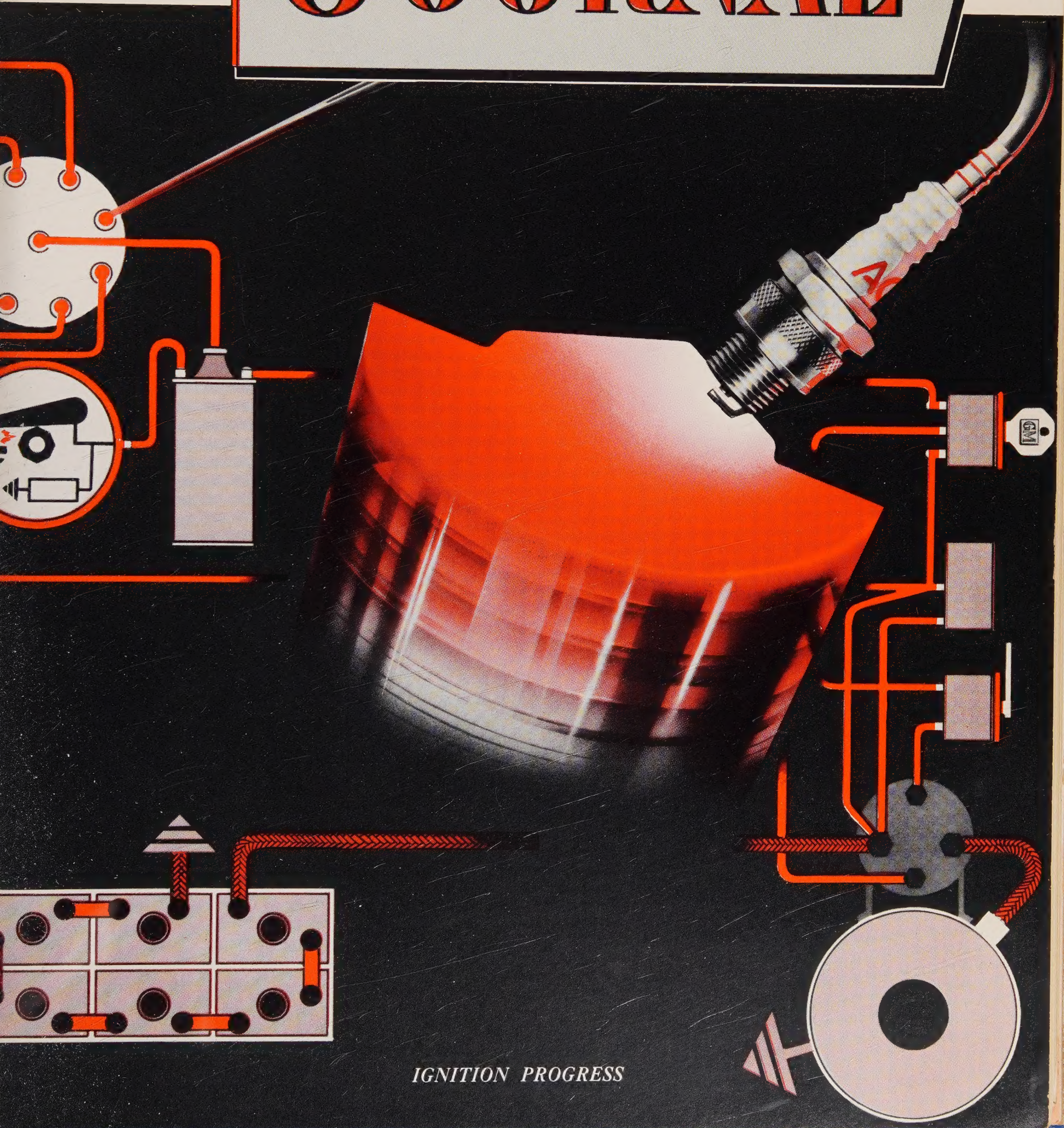
GENERAL MOTORS

Engineering JOURNAL

INDEX ISSUE

Volume 1 November-December 1954 Number 9



IGNITION PROGRESS

On Public Understanding of Engineering

THE engineer is at the core of our nation's industrial growth. He originates and develops the many products of our economy. Scarcely can you name a man-made thing that people see, feel, hear, or taste but that comes into usage through the touch of an engineer. Yet, the very people who derive the benefits of all these things do not fully appreciate the importance of engineering to their well-being.

The ever-forward movement of technology in an industrial organization like General Motors can hardly be brought to public notice on a day-to-day basis. So, periodically it is well to take stock of just what we have accomplished and examine how it has come about.

One such stock-taking is our celebration this November of the production in this country of GM's 50 millionth car. This unparalleled achievement serves to spotlight engineering progress, to epitomize how the engineer's creativeness and continuing search for better things—and better ways to make them—have resulted in an age of unprecedented technological advancement.

This GM feat in itself, in which thousands upon thousands of businesses all over the country have been partners, has had its impact in a truly revolutionary improvement in living standards for millions.

The annual GM Motorama also dramatizes the organization's engineering and research by exhibiting its newest models and by pointing into the future with dream cars and kitchens of tomorrow. The traveling Parade of Progress and the several domestic and overseas units of Previews of Progress are designed likewise to inform the public dramatically of its debt to technology.

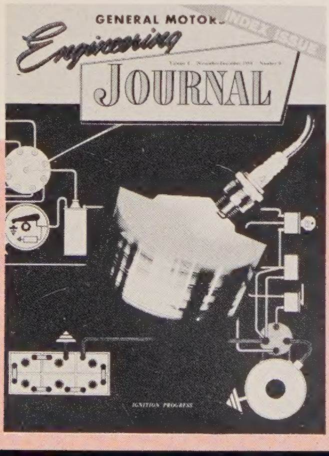
General Motors is concerned, too, with the development of a better mutual understanding within the engineering field between its own engineers and engineering educators. GENERAL MOTORS ENGINEERING JOURNAL is one medium for building that understanding. It was developed at the suggestion of engineering educators. It is designed primarily for distribution to them. The periodical's purpose is to contribute in the engineer's own language something of value to engineering education. The guidance of engineering educators themselves is sought in determining what material will be useful in engineering classrooms.

It is our hope that the efforts of our own engineer-contributors have proved of value to educators and to their students. Their objective in each paper is to strive for accuracy of expression and detail—in the full knowledge that time will make their writings obsolete. So rapidly does our technology move forward that information currently disclosed is likely soon to be superseded by new information and developments—sure to be, in part, the work of men now in college classrooms.

This is as it should be. The engineer and the scientist furnish the seeds from which come newer and better and more useful products for the future. Their contributions are made visible, in part, through an exchange of information in their respective fields. An important factor in the whole process is a truthful dramatization of technical developments for the understanding of the public upon whose support we are all dependent for future progress.

Paul Garrett

Paul Garrett,
Vice President in Charge
of Public Relations Staff



THE COVER

Another in a series of covers portraying transportation developments is this design by Artist John Tabb dealing with ignition in the internal combustion engine. Applying electrical fundamentals, engineers have developed better spark plugs and better ignition systems to produce a spark of proper characteristics to satisfy the new operating requirements of today's engines. The improvements in engine ignition have included a 12-volt supply, now used in some vehicles, and certain advances in spark plug design, such as the use of new insulating materials, new electrode materials, and new configurations of the insulator. Shown on the cover is a representative combustion chamber at the instant of explosion of the fuel-air mixture, in conjunction with other components of the automotive electrical system.

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GENERAL MOTORS

Engineering JOURNAL

Vol. 1 November-December 1954 No. 9

Published with the help of General Motors engineers everywhere

The GENERAL MOTORS ENGINEERING JOURNAL is published every other month by the Educational Relations Section of the Department of Public Relations, General Motors Corporation, and is intended primarily as a medium for presenting to the field of engineering education the results of General Motors research and engineering developments both in the product and production fields.

Address: EDUCATIONAL RELATIONS SECTION, Department of Public Relations, GM Technical Center, P.O. Box 177, North End Station, Detroit 2, Michigan.

Product and Production Engineers Join Forces to Make New Manufacturing Techniques Succeed

By WILLIAM A. FLETCHER
and
WILLIAM C. EDMUNDSON
Delco-Remy Division

Men tend to view things according to their experience rather than as the things actually are. Thus, the product engineer, in designing a part, is concerned with function, strength of materials, fit, and other similar factors. The production engineer looks at the part's manufacturability from a process and methods standpoint. Many manufacturing organizations have developed a group viewpoint in which product engineers and production engineers all contribute to production designs with the common goal of the most economical manufacture without sacrifice of quality. This cooperative atmosphere also underlies the development of special manufacturing machinery, the use of which often requires design modifications. A typical case example of how this joint approach operates is evident from a review of how Delco-Remy Division changed from a solid to a hollow armature shaft for its high-volume automotive generator production and its success in securing improved performance while reducing unit cost.

Can an armature shaft be hollow? Ask the generator

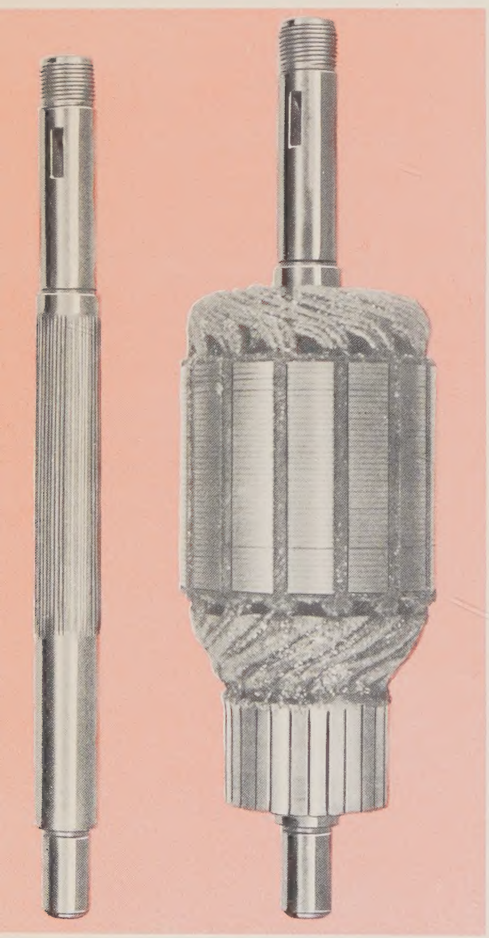


Fig. 1—An old model shaft and an assembled high-volume automotive generator armature. This conventional shaft was considered well-designed and properly processed.

IN ORDER to effect production economies by reduction of the material and labor required to make a part, it is necessary for the product engineer and the production engineer to work together on design modification. Even though the original design may have proved satisfactory over a number of years, it may be advisable, in view of the development of new manufacturing techniques, to redesign completely the part in question and perhaps even modify affected adjacent or related parts.

Although separate responsibilities are well-fixed, the cooperative working of the product engineer and the production engineer is widely practiced at Delco-Remy Division. A typical example of this type of cooperation was displayed in the redesign and reprocessing of the shaft for high-volume automotive generator armatures.

The old shaft was conventional and was considered well-designed and properly processed (Fig. 1). The shaft blank was turned on an automatic screw machine, centerless ground on the outside diameter *OD*, knurled on the OD, washed, and centerless ground on the bearing diameters. Then it had the keyways milled, threads rolled, and was inspected overall. There seemed to be no apparent opportunity to lower the cost of the shaft.

The production engineer studied the shaft with the thought that it might be redesigned for greater manufacturing economy and yet retain identical or better performance characteristics. Production engineers are more apt to be familiar with manufacturing methods than product engineers, since it is their prime function to accept a design and get it into the manufacturing channels. Thus, they often are in a position to aid in the redesign of parts when manufacturing economy is involved. The production engineer's objectives, in the case of the shaft, were to save material and labor—the same objectives which product engineers bear in mind when originating designs but without having the same level of manufacturing knowledge.

The production engineer first explored the possibility of extruding the various diameters of the shaft from a solid bar, which would have resulted in only a slight material savings. After some deliberation, he decided there was a possibility of making the shaft hollow, which would save a much larger percentage of material. While this idea had novelty in this specific application, it was not a revolutionary concept because power plant generator shafts were already made in that manner. The production engineer's familiarity with recent advances in the cold extrusion of welded steel tubing led him to believe that this manufacturing technique might be applied to the smaller, automotive-type armature shaft. Material-wise the strip steel for making welded tubing might cost more per pound, but the substantial weight decrease could mean a net gain in cost of sufficient amount to justify spending experimental time and money.

The product engineer and production engineer discussed the idea, and the product engineer began to redesign the part for manufacturability by the extrusion process. Nothing was to be sacrificed in performance and quality—that was a

basic ground rule. Since a hollow shaft of the same OD as the solid shaft would have less beam strength, the first step for the product engineer was to calculate what the new OD should be. The next modification of design was the switching from sharp steps in changes of diameter on the shaft to tapered reductions from one diameter to another. The extrusion process could not handle the sharp angles in the original design.

As the idea grew and developed new factors came to light. One basic engineering change found necessary was the method of holding the laminations of the armature on the shaft. On the solid shaft, serrations were knurled on the OD and these were more or less sheared into laminations at assembly in order to hold them. With a hollow shaft the OD can expand or contract to a certain extent when pressure is applied. After a few experiments of assembling laminations to prove that the method was sound, the production engineers and product engineers decided to allow a press fit between the laminations and the shaft rather than the knurled surface. It appeared that this would make an easier method of assembly and one capable of more accurate control on a production basis.

Fig. 2—Diagram of armature cross section showing the hole size necessary for an experimental hollow shaft of 1-in. outside diameter *OD*. The former shaft OD is indicated by the dotted line. The magnetic path in the armature laminations was so reduced by this hole that generator performance was lowered. Therefore, the shaft OD was reduced to 0.875 in., allowing a satisfactory magnetic path in the lamination.

Calculations for beam strength showed that a hollow shaft with the same strength as a solid one should have an OD of 1 in., compared to a former OD of 0.750 in.

In connection with this problem, the product engineer drew up an experimental design incorporating a 1-in. OD and the tapered steps from one diameter to another. Using this as a basis, the production engineer designed and made experimental tools to make a 1-in. OD hollow shaft. After some difficulties and a few tool changes he was able to make a few sample shafts. These shafts were then built into generator armatures and tested. The tests showed that the shafts were strong enough mechanically, but that the magnetic path in the armature laminations was reduced by the hole required for the larger shaft, resulting in lowered generator performance (Fig. 2).

A shaft of 0.875-in. OD was then given consideration. Calculations by the product engineer showed that the shaft would remain sufficiently rigid and the magnetic path in the laminations would be as satisfactory as with the solid shaft. The production engineer also made experimental tools and produced sample shafts of welded steel tubing for this experimental design (Fig. 3). These shafts were then built into armatures and tested. The results bore out advance calculations showing that the 0.875-in. diameter shaft with the laminations assembled on it was as strong as the solid shaft. Also, the output of the armature was up to electrical specifications in every way.

The experimental design of the 0.875-in. diameter shaft had a shoulder on the driven end which was to take the end thrust of the armature (Fig. 4a). The original idea was to shear this shoulder from part of the metal on the extruded angle of the shaft. On the actual performance and endurance tests of the first samples this shoulder proved to be too fragile. The product engineer informed the production engineer of the results and between them they decided to retain the shoulder, but to trim it down on the OD and move it back on the shaft to allow for the insertion of a thrust washer (Fig. 4b). In this case they were moving away from a good cost-saving idea, but it was necessary in order to make possible the basic material saving involved in switching to a hollow shaft. The production engineer gave way on a favored idea in order to attain a quality level required by the product engineer.

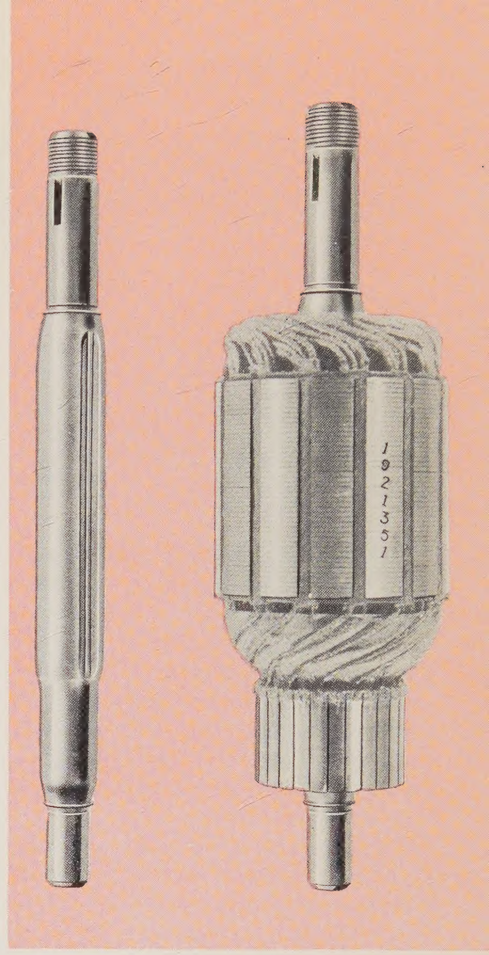


Fig. 3—A sample hollow shaft of welded sheet steel and an assembled generator armature. This shaft made possible savings in material costs while yielding the required performance. The successful design and manufacture of such a shaft demonstrates the effectiveness of design and production departmental cooperation.

Thus, by working together, the production engineer and product engineer were able to arrive at a successful hollow shaft design which would perform satisfactorily, and which was capable of being made by the cold extrusion process. Without this teamwork the probability of either alone being able to bring a design of this nature into being would have been very slight.

The hollow shaft-type armature was now ready for introduction to Delco-Remy's customers. Due to the major design change, they gave the armature a thorough testing. Endurance tests, road tests, acceleration tests, and strength tests were among the ones it had to pass. After the testing period, the customers were satisfied that the hollow shaft construction was capable of quality performance and approved it for production.

By this time other members of the production team had entered the picture.

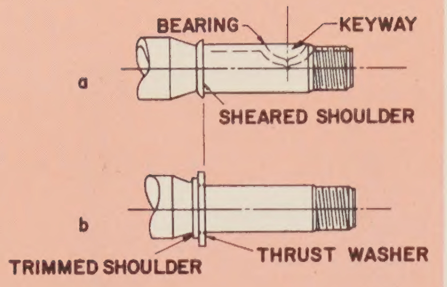


Fig. 4—The drive end of the hollow shaft. A shoulder sheared on the shaft (a) was originally intended to take the end thrust of the armature. However, performance and endurance tests proved this shoulder to be too fragile. The shoulder was consequently moved back on the shaft, the OD of the shoulder trimmed, and a thrust washer inserted (b).

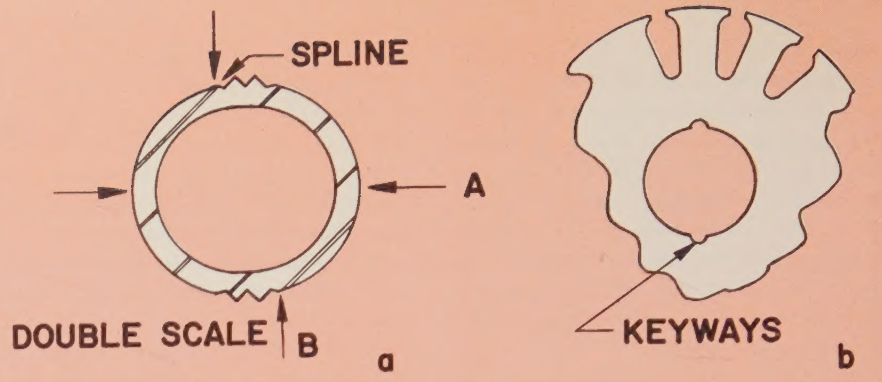


Fig. 5—In production, difficulty was experienced assembling shafts in laminations using the 0.008-in. press fit which was originally specified. To solve this problem, two splines were rolled on the shaft (a) which fit the keyways already in the lamination (b). When the splines were rolled on the shaft, dimension **A** became slightly larger than dimension **B**. The hole diameter in the lamination was then smaller than dimension **A** of the shaft, producing an interference fit between a portion of the shaft and lamination.

The production engineer submitted his sequence of operations to the tool design group for tooling, to the equipment engineer for machines to go with the tools, and to the plant engineering group for departmental layout. These groups, by working together, were able to design, construct, and place into operation a department to make hollow shafts by the extrusion process.

The manufacturing operations were arranged for a minimum of actual operators; for example, all transferring of shafts from operation to operation was made automatic. Thus, while the engineering department accomplished basic material savings by the new design, other departments contributed in a major way toward lowering the costs of manufacture by the more efficient use of men and machines.

Pilot production of the hollow shaft and assembly of the laminations were attended by routine difficulties, which are to be expected with new methods of manufacture. The first problem encountered was in the pressing of the laminations onto the shaft. The armatures that had been built earlier had 0.008-in. press fit between laminations and shaft. These laminations had been pressed on a few at a time, rather than all at once. Armatures made in this manner had proved satisfactory on the standard high-speed acceleration test.

When pilot production was started it was found that the laminations could not be placed on the shaft all at one time with the 0.008-in. press fit between diameters, since the great pressing force caused galling and bent shafts. Several ideas were advanced by the production engineer on how to assemble the laminations, such as knurling, splining, and assembly by steps. One of these proved successful. Two splines, which fit the keyways already in the lamination, were rolled on the shaft (Fig. 5 a & b). When the splines were rolled on the shaft, dimension **A** became slightly greater than dimension **B**. The hole diameter in the lamination was, therefore, made smaller than dimension **A** on the shaft. As a consequence, there was an interference fit between a portion of the shaft and the laminations. A special machine was built to perform this operation automatically. It also was found that the end laminations on the shaft were loose. Again a solution was found in a manufacturing method—the shearing up of four spots on the shaft to stake over the end laminations (Fig. 6). This proved to be a satisfactory solution to the problem, and was another example where the product engineer opened his mind to a new approach and evaluated the solution on its own merit in order to help the production engineer attain his goal. Again, special machinery made it possible to do this operation at no increase in labor cost.

The hollow extruded shaft was then put into production and the various economic reasons for developing it began to pay off. As is typical of most redesigned products, various other difficulties began to show up at the final inspection stage, making rework necessary before delivery. Some problems that seemed minor at the start took on major proportions with increases in the number of rejected parts.

One of these was the design of the keyway by which the pulley is affixed to the shaft. On the solid shaft, used previously, this keyway had been milled with a keyway cutter and had proven satisfactory. The hollow shaft had been tooled in a similar manner, but the milled keyway caused two difficulties.

First, the keyway left little support for the half-moon key (Fig. 7a). Secondly, when the keys were placed in the keyway they sometimes fell through or cocked. In the latter case, the cocked key sheared into the shaft when the pulley was placed on the shaft. The product engineer realized that a condition like this had to be corrected. He asked the production engineer if it might not be possible to shear or punch a keyway and leave a bottom in it. The problem was solved by shearing the keyway with a punch in a die set (Fig. 7b). This eliminated the falling through of keys, and also assured straight keys.

An additional result of this change was a substantial reduction in manufacturing costs, because shearing keyways is less expensive than machining them with conventional keyway cutters (Fig. 7). This is primarily true because of the expense involved in buying and maintaining a large number of accurate keyway cutters. Unless an expensive, special keyway cutter is used, the resulting size tolerances of the keyways are beyond what good engineering practice would dictate. With a sheared keyway the situation is a different story. The dies and punches are relatively inexpensive to make, they last a long time, and the resulting slot widths and depths are more accurate than the machined ones.

A second problem that showed up after production started was the lubrication of the shaft bearings. This difficulty was introduced due to the hollow shaft design. The centrifugal-type generator fan, and the radiator fan both draw air through the generator when it is mounted on an engine. This passage of air does not affect solid shaft bearings; however, with the hollow shaft construction, the product engineer found that dirt and

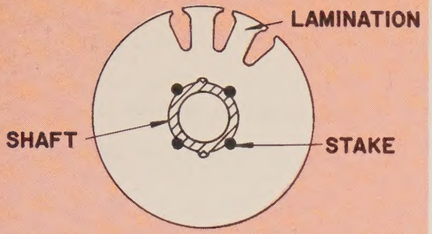


Fig. 6—Staking of end lamination. To solve the problem of loose end laminations on the hollow shaft, four spots were sheared up on the shaft to stake over the end laminations.

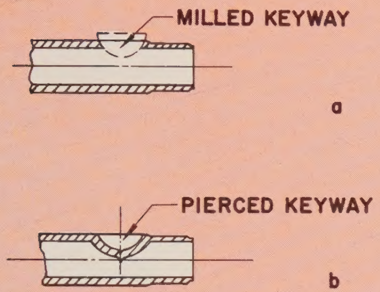


Fig. 7—In the early processing of hollow shafts, the keyways were milled with a keyway cutter as they had been on the solid shafts (a). Trouble resulted since there was little support remaining for the key. Moreover, keys sometimes fell through the keyways or cocked in assembly. Therefore, the keyways were sheared with a punch in a die set, eliminating these difficulties and bringing greater economy in processing.

Fig. 8—Lubrication problems with the shaft bearings arose when the hollow shaft was mounted on an engine. The cylindrical-type generator fan and the radiator fan both drew air through the generator causing dust and grit to enter the bearings through the hollow center of the shaft. This difficulty was eliminated by placing a rubber plug in the end of the shaft.

SEQUENCE OF OPERATIONS:
Solid Shaft versus Hollow, Extruded Shaft

SOLID SHAFT		EXTRUDED SHAFT	
Operation Number		Operation Number	
1.	Turn all diameters and cut off (an automatic screw machine)	1.	Roll tube from strip stock, weld, and cut to length)
		2.	Nose ends of tubes
2.	Centerless grind OD of shaft, rough, and finish	3.	Centerless grind OD of tubes, rough, and finish
		4.	Wash tube and coat with trisodium phosphate
		5.	Extrude drive end of shaft, shear thrust shoulder, and extrude extreme end for later thread rolling. Press with indexing dial
		6.	Machine drive end of shaft on special machine
		7.	Extrude commutator end of shaft, and shear oil slinger on second press
		8.	Machine commutator end of shaft
6.	Mill keyway	9.	Pierce keyway with press
4.	Wash	10.	Wash
5.	Centerless grind both bearing diameters of shaft	11.	Centerless grind both bearing diameters of shaft
7.	Roll threads with thread roller	12.	Roll threads with thread roller
3.	Knurl OD of shaft	13.	Roll splines on OD with special machine
8.	Inspect	14.	Inspect
9.	Ready to have laminations assembled	15.	Ready to have laminations assembled

Table I—A comparison of the sequence of operations in making a solid shaft and a hollow shaft. Some of the engineering changes necessary to bring the shaft to final production, such as piercing the keyways and rolling the splines, can be noted in the sequence of operations of the hollow shaft. In spite of the greater number of operations on the hollow shaft, the use of special machines in processing and savings in material expense made possible savings over the old method of more than twice those originally estimated when the design change was proposed.

grit could enter the bearings through the center of the shaft. He submitted this problem to the production engineer who solved the difficulty by placing a rubber plug in the end of the shaft (Fig. 8).

By this time, the other departments involved in the use of the hollow shaft had gained production experience, and it soon became clearly evident that the quality of the product coming off the line was better than had been obtainable with the solid shaft.

Other members of the manufacturing team had been closely following the progress of the hollow shaft. At first the shafts had been made from cold-rolled strip steel, which is more expensive then some other metals.

Due to the change from bar to sheet steel for the shaft, the quantity of strip stock used by Delco-Remy was increased. This increase, along with the use of slit-type, hot-rolled steel in other applications, made it possible for the production control group to justify the purchase of a rotary slitter. With this machine in use, large coils of stock could be purchased and then slit to suit Delco-Remy's requirements. The materials engineering section, the purchasing, and production control departments all realized that if hot-rolled slit steel could be used, a further reduction of cost on the shaft would be realized. Material of this sort is much less expensive than individual sizes from the steel mills.

Hot-rolled stock was procured, slit, and tried on the hollow shaft. It was very successful, and resulted in a still further decrease of shaft cost. By this time the various economic factors—saving of material, use of special machinery, changing from milled to pierced keyways, and changing from cold-rolled to hot-rolled slit stock—had more than doubled the original estimated savings.

Conclusion

Table I shows a comparison of the sequence of operations of making the solid shaft versus manufacture of the hollow extruded shaft. Some of the engineering changes required to bring the shaft to final production will be noted on the extruded shaft side of the chart.

This shaft project illustrates well that new production techniques, new equipment, or new materials usually require product design changes in order to put them into use. Only through the cooperation of product engineering and production engineering was it possible for the manufacturing economics of the hollow, extruded generator shaft to become a reality. Thus is underscored the growing trend of departmental cooperation and joint contribution of specialized skills and knowledge toward the general end of product improvement and cost savings.

An Automatic Load Control for Tuning-Fork Fatigue Test Equipment

By RAYMOND A. GALLANT
and
EDWARD K. BENDA
Research Laboratories Division

All engineers familiarize themselves with the properties of the materials with which they work. Since much of the loading which automotive parts endure under operating conditions is of a cyclic nature, engineers seek especially to learn the fatigue properties and the endurance limit of automotive materials. The need for this vital fatigue information has led to the development of specialized fatigue testing equipment. The requirements of accuracy and stability of operation of such equipment over extended periods of time have made necessary the development of carefully designed control systems for its regulation. One such control system which has proven very satisfactory is a servo system making use of the load itself as the basis of control for the fatigue testing machine.

Engineered uniform stress for millions of cycles

In the present-day development of automotive parts, the engineer is frequently concerned with the design of a member which will be subjected to fluctuating stresses. Then, in order to specify a given material appropriately, he learns in advance how anticipated fluctuating stresses on the road would affect the material; that is, he predetermines its fatigue properties.

It is commonly known that a piece of wire or sheet metal may be broken by repeated bending. If the degree of bending is severe, only a few cycles of flexure initiate failure in the material. If the amplitude of bending is lowered, the number of cycles endured will be greater; that is, life is increased. Finally, there exists for ferrous metals a certain amplitude of flexure or stress level below which fracture does not occur even after an infinite number of cycles. This stress level is called the *endurance* or *fatigue limit* of the material.

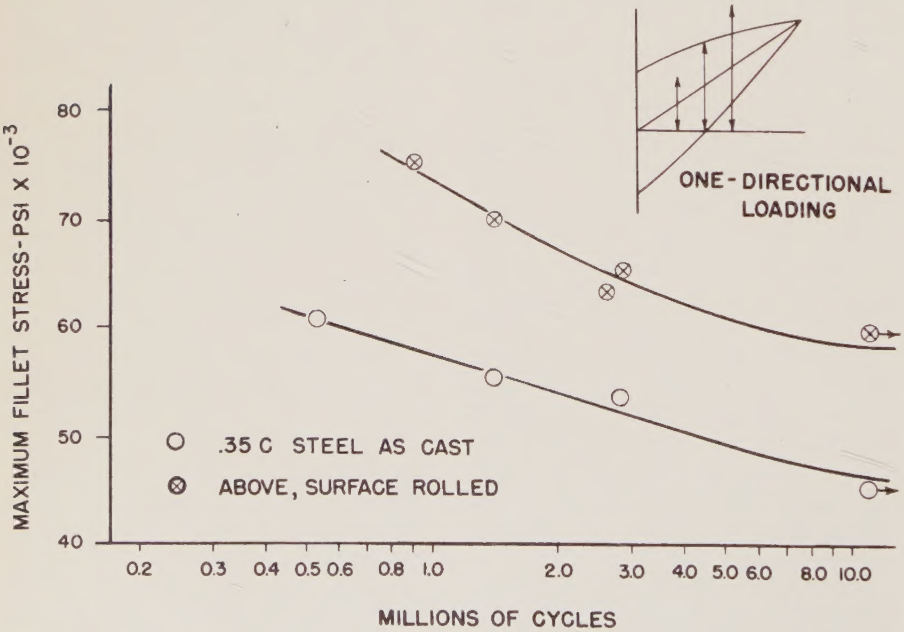


Fig. 1—Typical unidirectional fatigue curves. Some specimens, such as these for which *S-N* curves are shown, must be run for millions of cycles to obtain the desired data of their fatigue properties. It is, therefore, imperative that the equipment on which they are tested be controlled by automatic devices to maintain constant specimen load throughout the tests.

Since service loading is normally of a repeated type, the automotive designer must know the endurance limit of proposed material in order to determine whether its maximum safe working stress is above the expected requirements.

In order to gain this fatigue information, tests are conducted in the following manner. Several carefully prepared specimens of the contemplated material are placed in turn in a fatigue testing machine capable of applying a fluctuating stress of a known value until failure occurs. Tests are made at a number of different load levels. If, then, the value of stress level S is plotted against the number of cycles to failure N, an S-N diagram results (Fig. 1). Some specimens might run for millions of cycles before failure and, therefore, require considerable testing time. It is imperative then, from the standpoints of accuracy of results and economy of manpower, that the machine be provided with automatic control. Two such controls have been developed for use in the Research Laboratories Division. The particular machine for which these control systems were developed was placed in use more than ten years ago and the original control mechanism was quite different from the improved one now in use.

Tuning Fork Resonant Testing Machine

The fatigue testing machine announced in 1944 by the Research Laboratories Division is of the tuning-fork-type and was developed for full-scale testing of crankshaft sections. In this machine the specimen forms the crossover member between two large bars, or tines. If the system is excited into resonant vibration after the fashion of a common tuning fork,

large load fluctuations may be imposed upon the specimen with very little input energy.

The exciting force is provided by eccentric weights on the motor, attached to the bottom of one of the tines (Fig. 2). As the motor speed approaches the tuning fork resonant frequency, the lateral force of the eccentric weights excites a rapidly increasing amplitude of vibration of the tines, toward and away from one another at the frequency of motor rotation. This action imposes a correspondingly large alternating bending moment and associated stress upon the specimen. The magnitude of the applied moment is controlled by adjusting the motor speed as is shown by the curve of response of the system to forced vibration (Fig. 3). Since the curve is steep just below the resonant peak, operation in this region results in a large change in specimen load for a small change in motor speed. It is apparent, then, that a sensitive control might be based upon slight adjustment of motor speed in this zone, without materially affecting the rate at which cycles are accumulated.

Amplitude Control

The original control for the tuning fork machine, still usable but made obsolescent by the improved version, may be called an amplitude control for it adjusts the motor speed in such a manner as to limit continuously the maximum amplitude of vibration of the tines to a preset amount. This system utilizes the adjustable contact points shown in Fig. 2. By suitable instrumentation the specimen stress versus the gap between these points is determined and plotted as a calibration curve. Then to start a test, the desired gap is preset for the desired specimen stress and the machine started.

The controller is so arranged that the exciting motor speed tends to continue increasing unless contact is made between the control points. When contact is made, the electrical pulse generated is passed through a relay which actuates a servo motor which, in turn, changes a variable transformer setting in such a way as to decrease motor speed temporarily and eliminate contact between the points. The exciting motor speed then immediately increases until contact is remade and the cycle is continued. Thus, this system continually hunts about a "just contact" condition.

In its original application of controlling tests of crankshaft sections, this controller proved quite satisfactory since, in general, vehicle crankshaft failures have been attributed, for the most part, to resonant vibration involving both positive and negative stresses. If the laboratory tests subject the specimen to this type of stressing, known as *reversed stress*, no creep or permanent set occurs and load is proportional to amplitude throughout the test. However, in other applications amplitude control has disadvantages as compared with a system which would maintain a uniform maximum load throughout the test.

Control of amplitude of vibration can result in control of specimen stress only in a system which remains purely elastic so that stress is directly proportional to amplitude throughout the test. If, during the test, there is any small slippage in specimen clamping or any permanent set or yielding in the specimen, the tines no longer maintain their original geometry and the contact-gap setting changes.

Unidirectional stress cycles presented a special control problem, especially when testing softer materials. The tuning fork machine incorporates a pre-loading spring inserted between the lower ends of the tines to handle such unidirectional cycling. Experience has shown that yielding occurs early in the test. This yielding separates the tines a little beyond the preset contact amplitude and hence causes an unwanted increase in fluctuating or dynamic stress since the controller then operates at an increased gap amplitude.

Furthermore, the amplitude control principle allows the machine's load on the specimen to decrease when a crack is initiated because the weakened specimen, becoming slightly more flexible, no longer experiences the full original bending moment even though the original amplitude of tine vibration is maintained. This limitation is particularly important in the evaluation of materials subjected to surface cold working processes such as shot peening or rolling. In these cases, crack propagation may be extremely slow and, unless full bending moment is maintained, a positive indication of cycles to failure may not be obtained.

Lastly, the hunting about the desired control mentioned above causes fluctuations in the maximum amplitude of applied stress and, thus, introduces another possible source of error in the results of the tests.

In summary, the original control system using the amplitude principle was found satisfactory for many test applications. However, errors were introduced in the test results when the elasticity or clamping of the specimen was not maintained during a test, or when the elapsed time to failure became uncertain as the result of scarcely discernible failures. In seeking to reduce these errors, engineers decided to abandon the amplitude control principle in this machine and search for a better control factor. They reasoned that the specimen load itself, as the feedback portion of a closed servo control loop, would serve better.

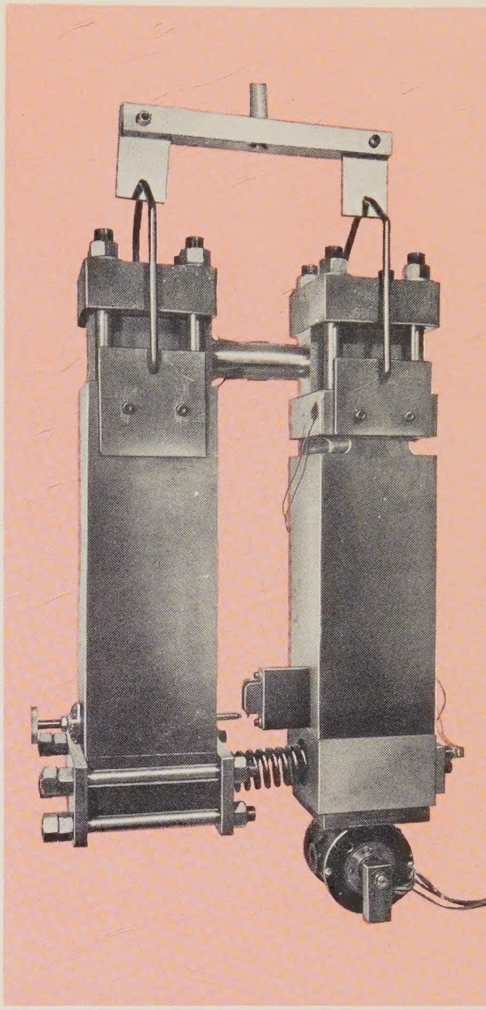


Fig. 2—A tuning-fork-type fatigue testing machine which was developed in 1944 by the Research Laboratories Division. In this machine the specimen forms the crossover member between the two large tines of the machine.

Load Control Principle Applied

Thus, a study was directed toward utilizing the load or stress in the test system as the primary control function. In such a system, the vibration amplitude

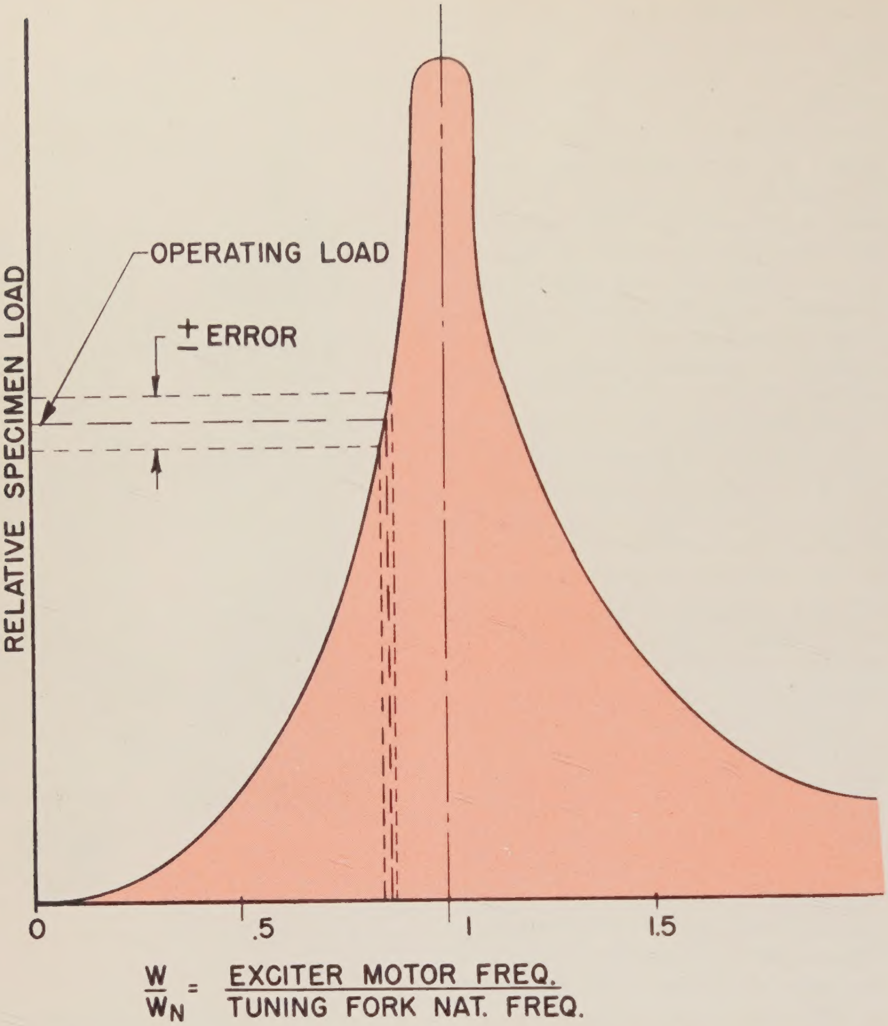


Fig. 3—Tuning fork response curve. When operating on a straight line portion of the response curve, a change in exciting motor speed produces a proportional change in the amplitude of vibration and, hence, a proportional change in the bending moment or stress in the specimen.

would be automatically adjusted to maintain a constant maximum bending moment in the specimen even if yielding occurred or if a crack were initiated. Furthermore, since continuous fluctuations in the system stress would be used as the basis of control, a proportional-type servo system having a definite equilibrium position was possible. Then, any deviation from this position would result in the production of a force which would return the system to equilibrium. This reasoning was reduced to practice and a successful control was developed. The shortcomings of the original system are eliminated in the new design.

Conventional SR-4 wire strain gages serve to measure the system stress. Two notches are cut in one tine of the fork to provide a stress concentration necessary to provide a gage output of an easily detectable level (Fig. 2). Furthermore, the shape of the notches allows mounting the gages with the grid length in the high strain area while the gage lead connections experience little or no strain. This condition, of course, tends to increase the life of the gages.

Two SR-4, C-10 gages of 1,000 ohms each are cemented in the notches, one in each notch. The d-c excitation for the gages is obtained from a highly filtered and stabilized power supply. This same power supply also furnishes a controllable d-c reference voltage to which the gage output is matched through the action of the servo system.

Any line or power supply variations which might pass through the regulated power supply are attentuated in the amplifier because its response is designed to drop off in amplitude below 20 cps and normal power supply variations occur at a rate below 10 cps. (Any attempt to operate below 10 cps could result in difficulty due to feed-through from the power supply.)

A block diagram of the complete servo control loop as required for the strain gage method of control is shown in Fig. 4. The operation of this servo loop may be described as follows. The a-c strain gage signal, which is proportional to specimen loading, is amplified and rectified to produce a proportionate d-c voltage level which is compared to the reference voltage. The difference between these two voltages, both in polarity and magnitude, becomes a d-c voltage level which now represents the difference between the actual and desired specimen stress or an error signal. Finally, this error signal is fed into a servo motor which, through a variable transformer, adjusts the voltage and thus the speed of the tuning fork exciting motor so as to bring the actual specimen stress to the desired value. In this manner, the error of the system is driven to zero.

The exciter motor used is a 1/20 hp, single-phase, high-slip, squirrel-cage construction, capacitor-run-type of motor. The high-slip construction permits a speed versus applied voltage characteristic which is suitable for controlling with a variable transformer.

The control box and tuning fork are shown in Fig. 5. The advantageous features of this control system include the following:

- A simple dial movement enables setting desired specimen load.
- Interlocks are arranged to prevent an initial overload of the test specimen and to bring the specimen up to the preset load automatically.
- A direct time indicator operates only during specimen testing.
- The complete power and control unit is integrated into one easily portable metal case.

The controller is connected to the testing apparatus through only two plug-in cables: one for strain gage leads and one for the exciter motor. An automatic shut-off switch turns off the equipment when the specimen is unable to maintain the desired bending moment, thus providing a definite criterion of failure.

Calibration

Calibration of the equipment may be accomplished by placing an additional

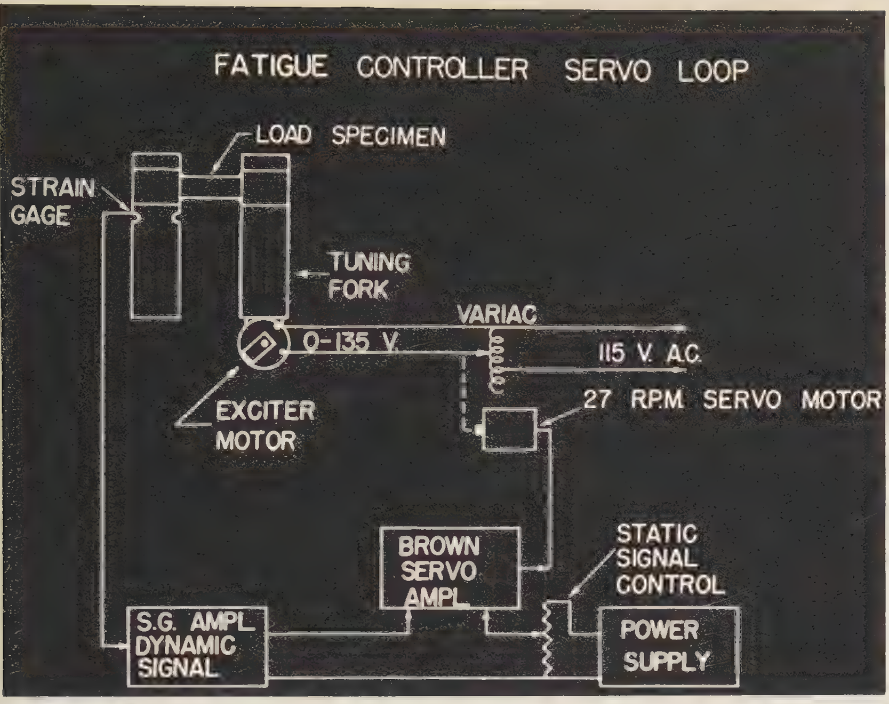


Fig. 4—Block diagram of the complete servo control loop as required for the strain gage method of control of the tuning-fork-type fatigue testing machine.

Fig. [illegible]—Tuning-fork-type fatigue testing machine and control box. One of the three [illegible] features of this strain control system is its compact quality. The complete power and control units are included in one easily portable metal case.

strain gage upon the specimen at the location of critical stress, and monitoring this gage output for a series of positions of the controller load-set dial. A curve of specimen stress versus dial setting is then the required calibration. Only one calibration need be performed for each given specimen design. Furthermore, for specimens of simple cross section, the system bending moment versus dial setting serves as a calibration.

An indication of the accuracy of control equipment of this nature can be determined by monitoring the actual specimen stress throughout a fatigue test. In evaluating the new control system several such monitoring tasks were completed. It was determined that, when operating on the essentially straight portion of the tuning fork response curve and at various specimen stresses in the range from 40,000 psi to 60,000 psi, the variation in stress imposed on the specimen was not more than ± 2 per cent of the desired value (Fig. 3). For specimen stresses from 60,000 psi to 120,000 psi, the load regulation was within ± 1 per cent, and for specimen stresses above the 120,000 psi double amplitude value the deviation was essentially zero. This range of specimen stress, 40,000 psi to 120,000 psi, corresponds to control notch stresses of only 3,000 psi to 10,000 psi because of the difference in respective moments of inertia. To operate outside these limits, certain changes, such as in magnitude of eccentric weight on the exciting motor shaft or in the time constant of the servo control system might be necessary. Furthermore, no slow drift of the controlled stress was found, even during continuous operation over the several days that some of the early tests were monitored.

Conclusion

The tuning fork fatigue testing control system using the load itself as the primary control function has proven very satisfactory for all applications made thus far in the Research Laboratories Division. Further, its use is not limited to the tuning fork machine described herein. A similar system may be used for control in any application, whether near resonance or not, wherein it is desirable to monitor loading at some convenient location in the system and where the stress level is not necessarily very great. Some modification of components of either the fatigue testing machine or of the control system might, of course, be necessary to bring about a satisfactory response for different applications.

Bibliography

Other related literature in this field includes the following:

Dolan, Thomas J., "Electrically Excited Resonant Type Fatigue Testing Equipment," *ASTM Bulletin*, No. 175 (July 1951).

Gadd, C. W. and Ochiltree, N. A., "Full Scale Fatigue Testing of Crankshafts," *Proceedings, Society for Experimental Stress Analysis*, Vol. II, No. 11 (1945), pp. 150-57.

DenHartog, J. P., *Mechanical Vibrations* (New York: McGraw-Hill Book Company, Inc., 1951), p. 61.

The Engineer and the Cooling-System Thermostat: A Story of Evolution

By HAROLD A. REYNOLDS*
Harrison
Radiator
Division

The engine became a better performer—so did the thermostat

Rapid warming of the engine coolant is of great importance in alleviating cylinder and piston ring wear due to water from the products of combustion condensating on the cylinder walls. The early automobile models had no special provisions for a device which would allow rapid engine warm up with the result that unsatisfactory engine performance was quite common, especially during cold-weather operation. When the advantages to be gained from controlled engine-coolant temperature were realized, the evolution of the cooling-system thermostat began. The early attempts at promoting rapid engine warm up and coolant temperature control were quite crude by present-day standards but they nevertheless represented great improvements in motor-car operation. As new engine designs were introduced, it became necessary to develop constantly new types of thermostats to meet the increased cooling-system requirements. The cooling-system thermostat of today is representative of years of developmental work on the part of the automotive engineer to perfect just one component part of an automobile.

Prior to 1920, motor car manufacturers made no special provision for controlling the engine-coolant temperature. There was always the danger of the engine coolant boiling during hot-weather operation, especially with the thermo-sylphon principle of coolant circulation. During cold weather, motorists had the alternative of storing their car or, if operating their vehicles, accepting the unsatisfactory performance of a cold engine. The engine warm-up period was excessively long during cold weather—especially with the pump or forced coolant-circulation system in which the pump would start to circulate the coolant just as soon as the engine started and, as a result, dissipated heat away from the cylinders just as fast as it was formed. A definite need existed for developing some type of a device which would afford control of the engine-coolant temperature.

The first step in the development of such a device was in the form of radiator-core covers ranging from cardboard masks to leather or fabric shrouds. These radiator core-covering devices were the outcome of a discovery made by motorists who operated their vehicles during cold weather and found that improved engine performance resulted when part of the exposed core was covered. The purpose of the core-covering devices, which could be adjusted to cover a portion or all of the exposed core, was to prevent the fan from drawing cold air through the core and assist in providing faster engine warm up. The covers were left on until the engine became warm and were then removed—a requirement which was often overlooked.

The radiator core-covering devices were used quite extensively by motorists but the results achieved were not entirely satisfactory. Due to the unstable cooling demands in motor-car operation resulting from variable speed, load, and atmospheric conditions, it was difficult to adjust the covering devices to give the desired engine operating temperature. Rather than manually adjust the radiator-core cover to suit the prevailing conditions, motorists allowed their car's engine to operate at excessive temperatures. This practice caused eventual boiling and subsequent loss of substantial quantities of the engine coolant and a reduction in antifreeze protection. Replacement of the antifreeze which, during this period, was primarily alcohol became a very annoying and expensive habit because of the frequent occasions on which it was required.

The realization of the advantages of higher engine-temperature operation during cold weather and the unreliable results obtained with the radiator core-covering devices created an incentive and a potential for automotive engineers to develop a more satisfactory engine temperature-control device. It was recognized that a problem existed which should be solved by some form of mechanical application.

Manually Controlled Shutters

The first mechanical application approach to the engine temperature-control problem was in the use of radiator shutters or dampers which were mounted to the shell supporting the radiator core. The shutters, which were either horizontal or vertical, were manually operated and controlled by the driver with the aid of a pull rod which was mounted on the dashboard. When the engine was started the shutters were placed in the closed position, thereby blocking the passage of air through the radiator core and facilitating engine warm up. When the engine coolant reached the normal operating temperature the shutters were opened. The driver then controlled the shutters so as to regulate the air flow through the core and maintain the desired coolant temperature.

Although the manually controlled shutters represented a great improvement over the radiator core-covering devices, they still required continual attention and frequent adjustment by the driver while the car was in motion. In many instances, the required adjustment was neglected and serious overheating of the engine and loss of coolant resulted.

Thermostatically Controlled Shutters

The automotive engineer, in an effort to relieve the driver of having to operate and control the radiator shutters manually, concentrated on perfecting an automatic control mechanism. The result was the development of thermo-

*For Mr. Reynolds' biography and photograph, please see p. 51 of the January-February 1954 General Motors Engineering Journal. This is the second paper contributed by Mr. Reynolds, assistant chief product engineer in the Automotive Section of Harrison Radiator Division, Lockport, New York.

statically controlled shutters. The amount of shutter-blade opening was automatically regulated by a bellows-type thermostat which was placed in the upper tank of the radiator and was in direct contact with the circulating engine coolant.

The bellows of the thermostat were of the sylphon-type. This type of bellows consisted of cylindrical, thin-walled, metal convolutions assembled end to end, and usually mounted in a flanged, cup-shaped container which was assembled to the top tank of the radiator to insure flow of the engine-coolant liquid around the cup. The convolutions of the bellows were either hydraulically or mechanically formed from a light-wall, extruded or drawn, copper or bronze tube. The temperature-sensitive operating charge of the thermostat usually consisted of a specified amount of volatile fluid which changed into a gas and exerted internal pressure when the coolant reached a temperature of approximately 150° F. The operating charge was contained between the bellows case and external surface of the convolutions. This design exposed less surface area in contact with the engine coolant but simplified assembly and provided a ready means for attaching the connecting linkage of the shutter operating bar.

The early shutter-blade designs were all of the edge-fulcrum-type which afforded simplicity in manufacture and assembly but produced an unbalanced surface against the air pressure to which the blades were subjected by the forward motion of the car. As a result, the blades had to be counterbalanced by a tension spring to prevent them from blowing open. A spring tension of from 13 lb to 15 lb was found to be quite satisfactory up to a car speed of 50 mph. Because the thermostat was required to operate against and overcome this additional spring load, some delayed action took place in opening the shutters.

Although not perfect, the thermostatically controlled shutter arrangement was favorably received by the motoring public and was accepted by engineers as a gain—but not the final one.

Hot Water Heaters

The engine-coolant temperature control afforded by the thermostatically controlled shutters provided a ready source of hot water during cold weather which the automotive engineer was quick to turn to his advantage for car-heating purposes. Prior to the introduction of the thermostat for controlling the engine-coolant temperature, a hot-air type of heater, which derived its heat from the exhaust gases, had been used. Public disfavor of the hot-air exhaust heater, which was extremely dangerous due to the possibility of carbon monoxide fumes penetrating the passenger compartment, accelerated the demand for the hot-water type of heater.

Developmental work on hot water heaters resulted in a unit which was mounted on the inside of the dash (Fig. 1). The hot water circulated through the heater assembly and warmed the air which was uniformly circulated throughout the car's interior by a fan driven by a small electric motor. The hot water heating unit, which was manufactured as an accessory item, gained wide acceptance by the motoring public and the demand for this type of heater reached the point where car manufacturers provided specific locations on the inside of the dash for mounting the heater.

Although the thermostatically controlled shutters adequately controlled the engine-coolant temperature for satisfactory engine operation, they had three basic faults as a temperature-control device for car heating purposes. The shutters would not seal tightly enough to maintain a constant engine-coolant temperature for heating purposes. This was especially true at high car-speed operation when there was a tendency for the shutters to blow open and permit circulation of cooling air which reduced the coolant-liquid temperature below the level required for adequate car heating. The shutters also would stick or freeze shut under snow, sleet, or dirt conditions or when the shutter blades were bent enough to cause excessive friction at the fulcrum pins. The third basic fault was that, combined with the necessity for heating all of the coolant in the system, initial engine warm up was excessive due to air leakage past the shutter blades.

Because of the shortcomings of the thermostatically controlled shutters, research and developmental work was initiated by automotive engineers in an attempt to eliminate the shutter-type coolant temperature control and to perfect a suitable cooling system thermostat which would provide adequate coolant temperature control for car heating and satisfactory engine operation.

Fig. 1—The introduction of the thermostat for controlling engine coolant temperature made possible the development of the hot water heater. Pictured above is an early type of hot water heater which was mounted on the inside of the dash and provided a moderate amount of heat to the front passenger compartment.

Blocking-Type Hose-Line Thermostats

The next development in the evolution of the cooling-system thermostat was the introduction of a blocking-type thermostat which was located in the hose line connecting the cylinder head coolant outlet to the upper radiator tank. This type of thermostat also was available for cylinder head installation but many cars were not yet equipped with cylinder head receptacles and, therefore, required the hose-line type of installation. The blocking-type thermostat was designed to eliminate circulation of the coolant through the radiator during the warm-up period and allow circulation only through the cylinder block and head.

Two blocking-type hose-line thermostats were developed, both of which utilized butterfly valves to permit maximum flow with minimum restriction in the confined orifice available in the hose line. The two thermostats differed in the design of the thermostatic elements. One type utilized a closely coiled, bimetal surface which was exposed to the engine coolant. The differential expansion characteristics of the two metals provided the necessary power motion to open and close the butterfly valve. The second type of blocking thermostat used a power element which incorporated a fully evacuated bellows charged with a small amount of volatile fluid. The bellows evacuation held the

Fig. 2—The blocking-type of hose-line thermostat was designed for placement in the hose line connecting the cylinder-head coolant outlet to the upper radiator tank. The purpose of this early design of thermostat was to prevent circulation of engine coolant through the radiator during engine warm up. The thermostat unit was also adaptable to cylinder head installation on engines which incorporated thermostat receptacles.

Fig. 3—The built-up type of bellows was developed to improve flexibility and insure a lower and more uniform spring rate. The convolutions of the bellows were composed of individual discs stamped from sheet stock and were lockseamed and soldered together.

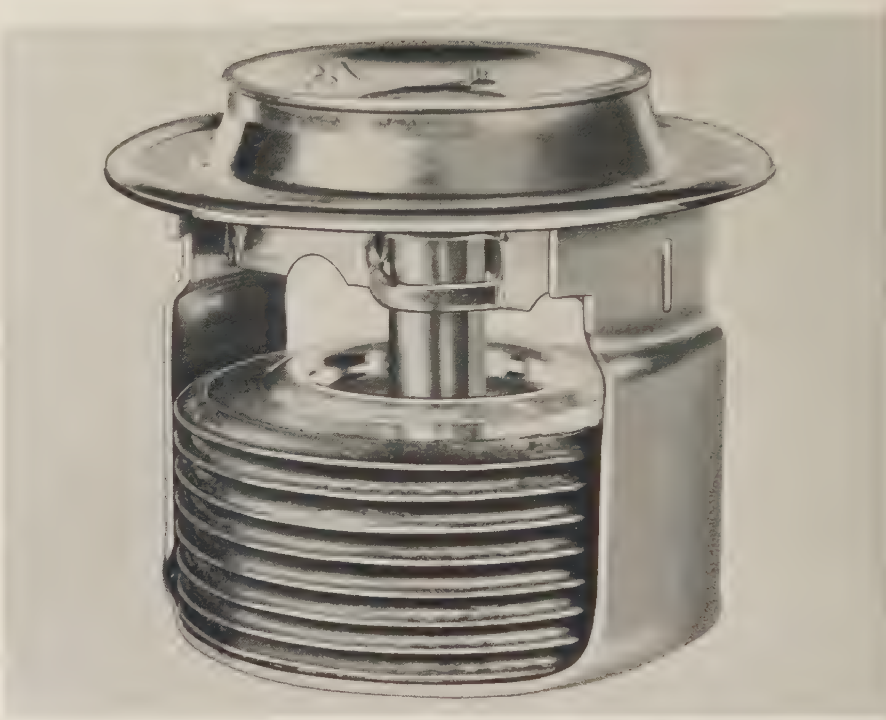


Fig. 4—The poppet-valve built-up bellows thermostat represented a great improvement in thermostat design and was used successfully from 1932 to 1952 on atmospheric and low-pressure cooling systems without any major change in design being required.

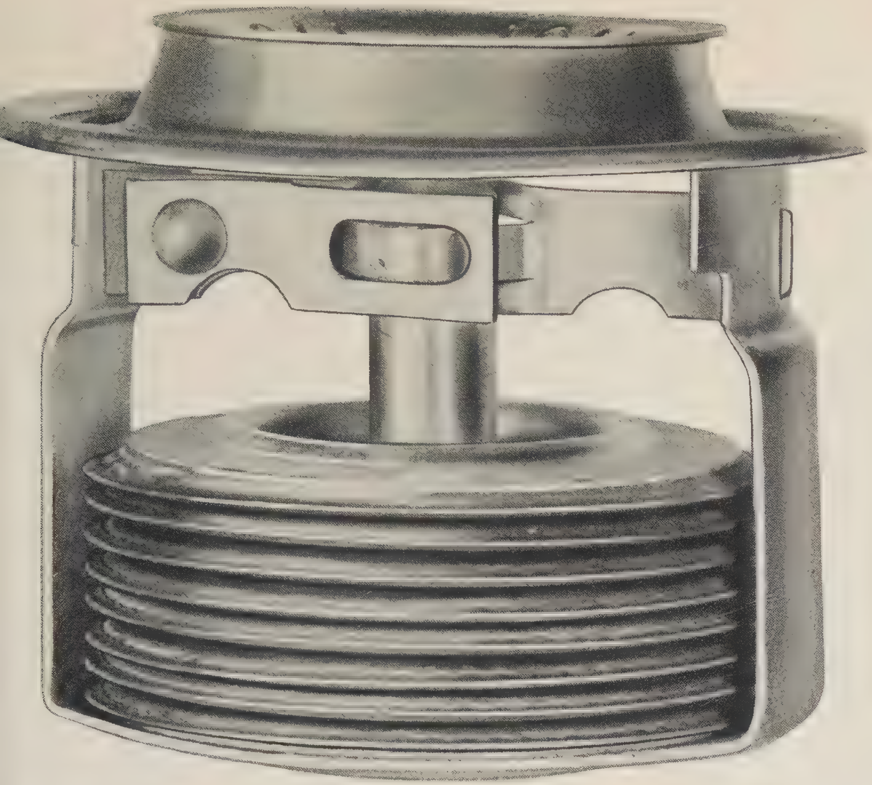
butterfly valve closed until the increased temperature of the coolant vaporized the fluid creating a pressure inside the bellows and causing them to expand and open the butterfly valve.

Under normal operating conditions, the second type of hose-line thermostat provided an improvement in the warm-up period and greater uniformity of coolant temperature control. There was, however, one fault in the operation of this type of hose-line thermostat. At high engine speeds there was a tendency for the butterfly valve to be forced open by the water-pump pressure. This action reduced the engine-coolant temperature below the level required for satisfactory car heating.

The Harrison Radiator Division's design of the blocking-type hose-line thermostat incorporated the commonly used butterfly valve actuated by a one-piece sylphon-type bellows (Fig. 2). In an attempt to correct the blow-by characteristics of this type of thermostat, the initial design had purposely incorporated a slight overbalance of the butterfly valve. This type of design had the desired effect of overcoming blow-by but caused the butterfly valve to remain closed when the bellows failed. This resulted in overheating of the engine and loss of the coolant.

Metal fractures, created by stresses in the forming of the convolutions, caused the bellows to have a short life. In most instances, the metal fractures could be traced to defects, such as local hard spots, laminated metal, and inclusions, which were not readily evident in inspection prior to the convolution-forming operation. If the defect occurred at the highly stressed portion, such as the external or internal radius of the convolution, the result was either immediate or early failure at the point of defect.

The unsatisfactory temperature control during high-speed operation and the



ig. 5—To prevent bellows failure resulting from igh-frequency vibration due to intermittent ulsation of the liquid circuit, a vibration damp- ner had to be used on poppet-valve thermostats laced in cooling systems of high speed engines. A flat spring riveted to the poppet-valve stem uide exerts a pressure against the stem and ampens the high-frequency vibrations.

omewhat erratic life of the blocking-type hermostat prompted further develop- mental work to be undertaken in order o produce a thermostat which would nsure better preformance of car heaters under all types of driving conditions.

Poppet Valve, Built-Up Bellows Thermostat

The difficulty encountered in con- rolling the metal uniformity of the xtruded cylinder from which the one- iece sylphon-type bellows were formed rompted Harrison Radiator engineers o develop the built-up type of bellows Fig. 3). With this type of bellows, the onvolutions were formed from indi- idual discs which were stamped from heet stock. In this way the base material vas subject to better control for such actors as gage, temper, grain size, and luctility and any defects present could e readily noticed by visual inspection. Flanged and unflanged discs were rolled ogether to form lockseams at the inner nd outer edges of the bellows. The lock- eams were then bonded with solder by immersion in a molten-solder bath.

An overall improvement in engine-coolant temperature control and thermostat service life developed when a poppet valve replaced the butterfly-type. Thorough and exhaustive tests, under all phases of car operation, showed that the poppet valve had distinct advantages. By balancing the effective area of the built-up bellows with the poppet-valve port area, the tendency for the thermostat to blow open or be affected by variable water-pump pressures was completely controlled through all car-speed ranges.

The performance of the poppet-valve, built-up bellows thermostat in controlling the coolant temperature under all types of car operation and in providing adequate coolant temperatures for car heating purposes was extremely satisfactory (Fig. 4). It proved so satisfactory that it was used almost exclusively for the next two decades—1932 to 1952—without any major change in the design of the thermostat control unit being required.

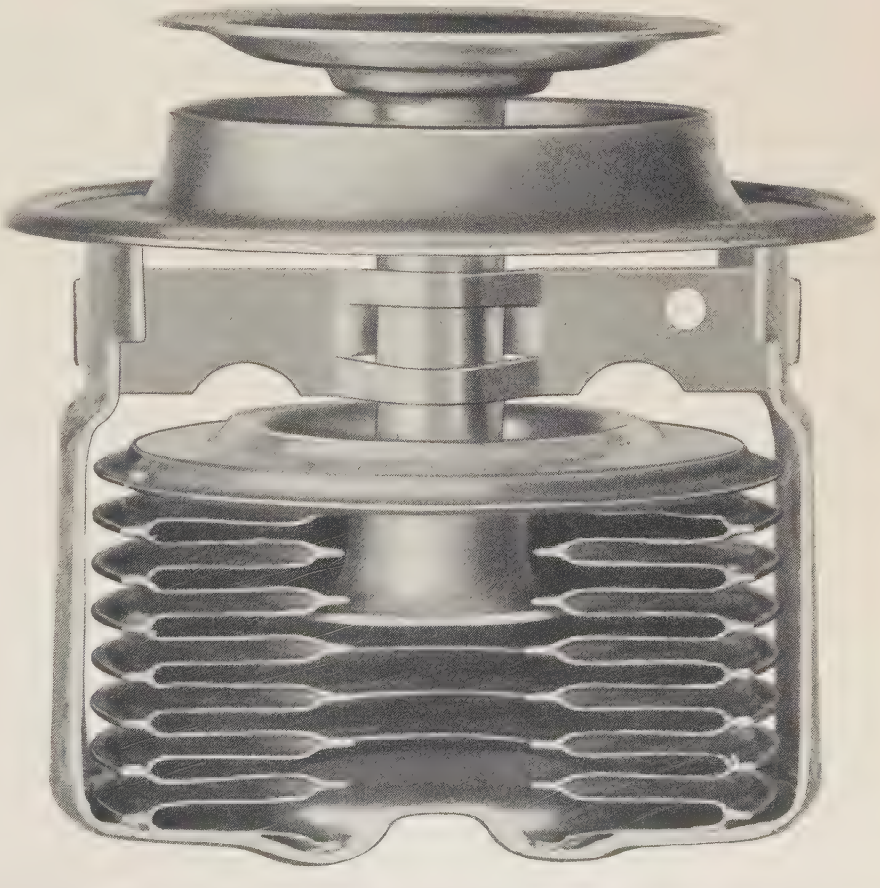


Fig. 6—Completely filling the bellows with the charge liquid and restricting the flow of liquid between the bellows convolutions and the hat-shaped dash-pot dampener effectively control bellows vibration.

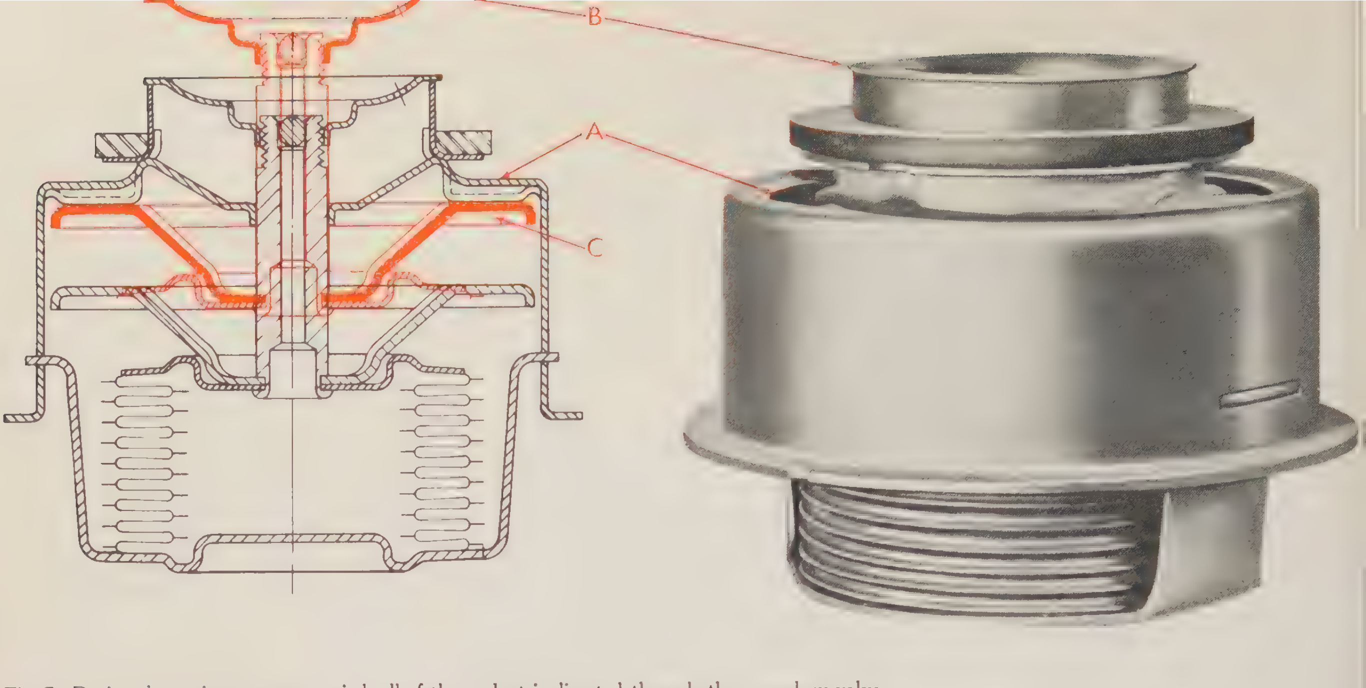


Fig. 7—During the engine warm-up period, all of the coolant is diverted through the secondary valve ports **A** of the by-pass-type thermostat. As the primary valve **B** opens, the secondary valve **C** closes, gradually reducing the by-pass volume as the flow to the radiator increases. Full flow of coolant to the radiator takes place when the primary valve is completely open and the secondary valve is completely closed (upper left).

Bellows Vibration

When thermostats are used in the cooling system of extremely high speed engines, for example, the modern Diesel engine, the intermittent pulsation of the liquid circuit causes a high-frequency vibration which has a serious effect on the life of the bellows. In view of this, in recent years a minor revision has been made to the basic design of the poppet-valve, built-up bellows thermostat. The revision has been the addition of a vibration dampener which, although it has no effect on thermostatic control, was found to be beneficial in protecting the bellows from failure (Fig. 5).

The bellows vibration dampening effect may be accomplished by two different and equally effective methods. In one case, a thin, flat, phosphor-bronze spring is riveted to the poppet-valve stem guide. The spring exerts pressure against the stem and retards the more or less free action of the poppet-valve impulses which were found to be over 5,000 per sec when observed with a high speed camera under laboratory conditions. If the bellows were allowed to vibrate at this rate, the thin metal of the bellows convolutions would fail in less than one minute. The addition of the friction applied against the poppet-valve stem effectively controls the transmission of high-frequency vibration to the bellows and eliminates the possibility of bellows failure.

The second method of bellows vibration dampening involves completely filling the bellows with the charge liquid instead of the normal 3-cc load required for temperature operation. A dash pot also is installed and is fastened to the upper header and operates in the liquid-filled chamber formed by the bellows convolutions (Fig. 6). Because of the manufacturing advantages obtained and the freedom from effect on still water start-to-open temperature, this type of thermostat is preferred and recommended for installations where protection from high-frequency vibration impulses is required.

By-Pass Thermostats

The necessity for allowing a full flow of engine coolant to maintain comparable metal temperatures throughout the engine and prevent hot spots which could cause local boiling and introduce objectionable vaporization and detonation, brought about the development of the by-pass type of poppet-valve thermostat (Fig. 7). With this design, the flow of coolant to the radiator is controlled by a primary valve, which operates in the same manner as the blocking-type thermostat, and also is equipped with a secondary valve which is wide open when the primary valve is on its seat.

During the warm-up period, or until sufficient temperature is developed to open the primary valve, all of the coolant is diverted through the secondary valve ports **A** to cored passages in the cylinder block and re-circulated throughout the engine. The primary and secondary valves are both attached to the poppet-valve stem and their movement is controlled by the action of the bellows. As the primary valve **B** opens, the secondary valve **C** closes and gradually reduces the by-pass volume as the coolant flow to the radiator increases. The secondary valve is fully closed when the primary valve is wide open which eliminates further by-passing and permits the full discharge of the water pump to be circulated throughout the cooling system. Installation of the by-pass-type thermostat is limited to engines which have been designed to accommodate the by-pass circulation and, therefore, cannot be installed in many instances where these provisions have not been incorporated.

The by-pass circulation on engines not designed for the by-pass, poppet-valve thermostat is usually of the partial-flow- or permanent-bleed-type. A small portion of the coolant flow, independent of the flow through the radiator, is diverted through an orifice in the water pump and circulates through the water jacket sur-

rounding the cylinders and cylinder heads.

Plastic-Element Thermostats

Since the end of World War II, there has been a steady increase in engine power and performance specifications coupled with a constant effort by the automotive engineer to reduce the cooling-system copper requirements. As a result, smaller size radiators have been introduced. In order to maintain the desired cooling index with the smaller size radiators and still meet the increased cooling demands, the cooling system has been placed under high-pressure operating conditions.

Bellows-type poppet-valve thermostats, used successfully with atmospheric- or low-pressure cooling systems, do not conform to all of the specified control requirements when installed in high-pressure cooling systems. Because this type of thermostat is charged with a compressible gas, it is sensitive to cooling-system pressure and its control characteristics are affected in direct proportion to the cooling-system pressure. Valve openings may be delayed as much as 20° F with a 7½ lb per sq in. pressure system and 30° F with a 13 lb per sq in. pressure system.

To eliminate the effect of cooling-system pressure on temperature control, automotive engineers have developed a power unit which utilizes a plastic element that is not affected by pressure (Fig. 8). A special form of wax-base plastic is fractionated by a distilling process to produce the desired expansion rate at a pre-selected temperature range. An extruded pellet of the wax-base plastic material is then compressed into a copper cup which is assembled to the cylinder of the power element. A diaphragm of expansible material separates the wax from the cylinder chamber and provides the required seal between the wax and the piston chamber. Expansion and contraction of the wax in the copper cup, which is exposed to temperature changes of the circulating engine coolant, causes motion to be transmitted through the diaphragm to a piston connected to a butterfly-type valve. This action results in the desired opening and closing cycles within the pre-selected temperature range. On the cooling cycle, as the wax contracts the valve is mechanically returned to its seat with the aid of tension springs.

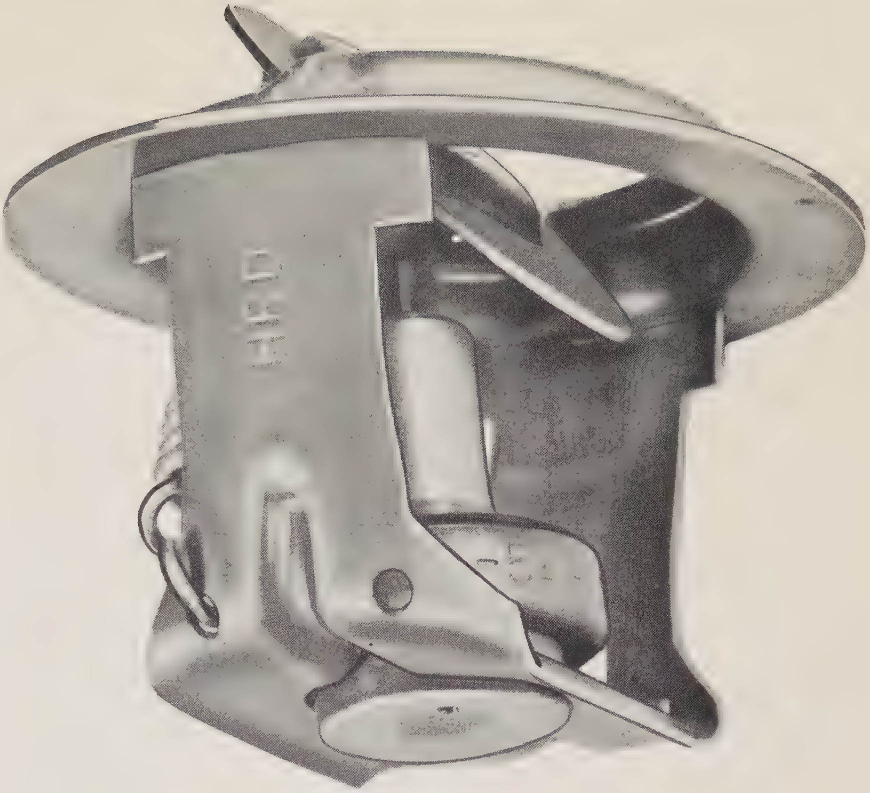


Fig. 8—Plastic-element thermostat developed to eliminate sensitivity of cooling-system pressure on temperature control. The wax-base plastic material used as the power element of the thermostat is not affected by pressure. This type of thermostat is recommended for cooling-system pressures in excess of 7½ lb per sq in.

This type of thermostat, because of its insensitivity to cooling-system operating pressure, is generally specified and recommended for cooling-system pressure operation in excess of 7½ lb per sq in.

Summary

The performance characteristics and reliability of present-day engine-coolant temperature-control thermostats represent a distinct improvement over those formerly used. The constant change in engine design through the years and the ever-changing operating conditions introduced new problems in cooling-system temperature control which the automotive engineer had to overcome before the ultimate goal of perfecting a suitable thermostat could be reached.

The evolution of the cooling-system thermostat has not ended. New thermostat designs will continue to be introduced along with new engine designs which will further enhance the uniformity of engine temperature control and extend the normal operating life far beyond that obtainable with present-day thermostats.

Bibliography

Other related literature in this field includes the following:

Eskin, S. G. and Fritze, J. R., "Thermostatic Bi-Metals," *A.S.M.E. Transactions* (July 1940), pp. 433-40.

Hundley, R. A., "New Concept of Internal Combustion Engine Cooling," *S.A.E. Journal*, Vol. 58, No. 11 (November 1950), pp. 33-9.

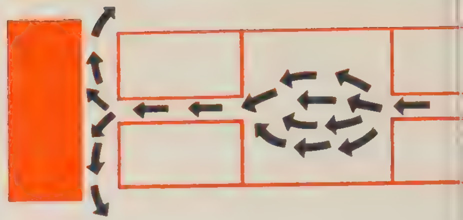
Koffman, J. L., "Cooling System Thermostats," *Diesel Railway Traction*, Vol. 6, No. 239 (April 1952), pp. 87-91.

Timoshenko, S., "Analysis of Bi-Metal Thermostats," *Journal of the Optical Society of America and Review of Scientific Instruments*, Vol. II (1925), pp. 233-55.

......, *Maintenance of Automotive Engine Cooling Systems* (New York: Society of Automotive Engineers).

Dyke, A. L., *Dyke's Automobile and Gasoline Engine Encyclopedia* (1950, 22nd Edition), pp. 145-56, p. 1056, pp. 653-54.

Factors Involved in the Use of Air for Precision Measurement



The use of air for the measurement of accurately held dimensions in the manufacturing plant is not new. Applications of this method were used in some General Motors Divisions as early as World War I. Not until the occurrence of the production requirements of World War II, however, did air gaging become widely accepted in industry. Formerly, the building and operation of air gages was largely on a cut-and-try basis. Today, accurate engineering design data and the use of reference curves permit precise calculation of all factors by the designer. As a result, the modern precision air gage is economical, trouble-free, accurate, and is easily operated by factory personnel.

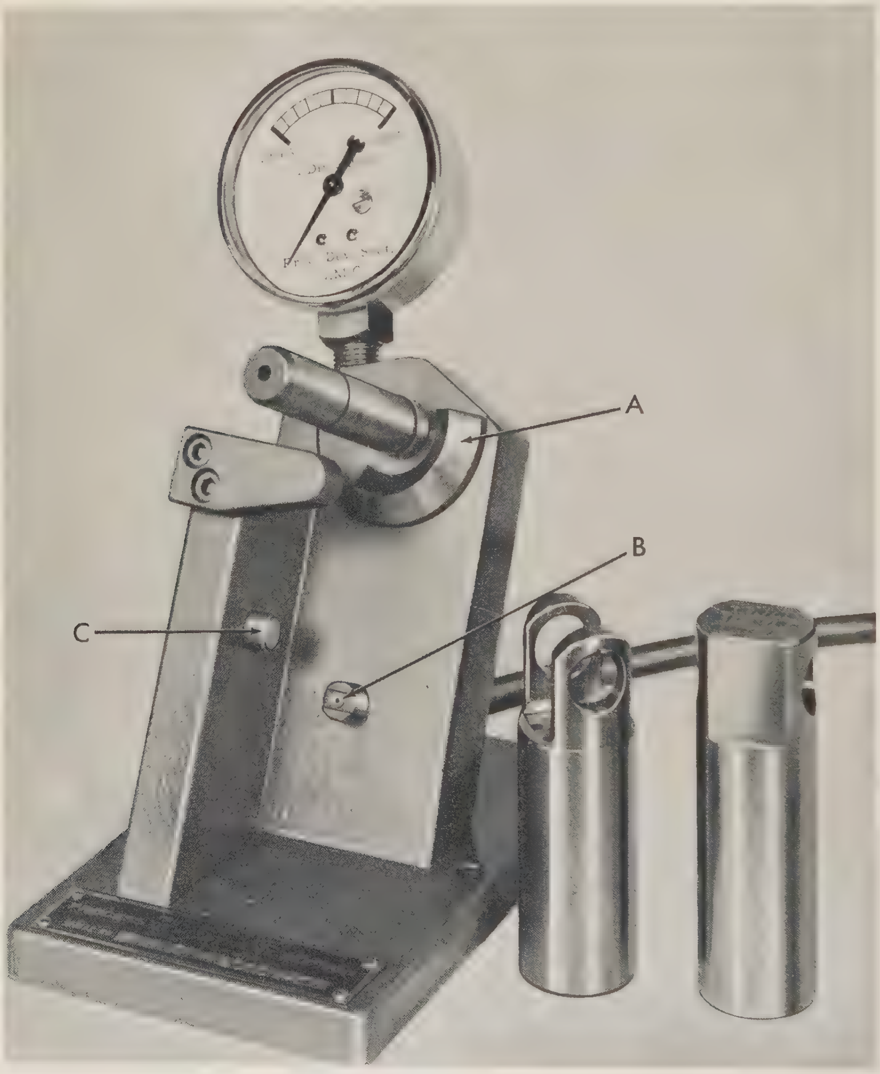


Fig. 1—A simple application of air gaging for precision measurement is this gage used to check squareness. A cam-roller follower body, shown beside the gage, must have its outside diameter (OD) checked with relation to the axis of a roller pin which is inserted in the yoke of the follower. When placed on the gage, the part is positioned against a circular anvil **A** at the rear. This anvil references the part with the air jet **B**. The rest pad **C** assures that the major diameter is on the centerline of the jet opening.

THE WIDE USE in industry of air as a means of gaging accurately held dimensions has occurred principally during the last decade. Little textbook information of air gage construction or application has been available in the past with the result that many types of measurement devices were built using cut-and-try methods. In General Motors, the experience gained in several of its Divisions and in the Process Development Section has led to certain established data and reference curves which now aid in the design and application of improved gaging equipment.

There is no conclusive evidence as to the exact inception of the idea of using air as a means of measurement. It is generally accepted, however, that its first industrial use was in the form of simple cylindrical air-plug gages used in the measurement of jet-orifice size.

Air plugs or spindles were used to check the inside diameter of holes. When affixed to a slender rod they were especially useful in gaging the bores of gun barrels which could not otherwise be accurately gaged for their full length. By passing the air plugs into the bore and reading the back pressure on a dial gage, the diameter, taper, and out-of-round of the gun barrel could be readily determined.

Present-day gages are more versatile and are able to measure dimensional tolerance on any shape or part. In addition to dimensional measurement, air gages check functions such as flatness, squareness, concentricity, out-of-round, and surface finish in some applications. A typical modern gage is shown in Fig. 1.

By CHARLES W. GARDNER
Process
Development
Section

Accurate production gages built from established data

Basic Principles of Air Gage Measurement

There are two basic types of air gages and, as far as principles are concerned, they differ only in the size-indicating mechanism employed to show visually what is occurring at the measuring air jet.

The first type of air gage makes use of the *flow system* in which a flow meter indicates the variation in air flow caused by a change in distance from the part surface being gaged to the measuring air jet. The flow meter can be calibrated to show a unit change in flow for each unit change in distance at the air jet.

The second type of air gage is the *back-pressure system*. This name is derived from the fact that a standard Bourdon Tube or Diaphragm Dial Gage is used to measure back-pressure build-up occurring when air flow from a measuring air jet is restricted by the close proximity of the part being gaged. This paper deals with gages of the latter type.

The basic components and pneumatic circuit arrangement of a simple back-pressure air gage are illustrated in Fig. 2. The filter in the system insures delivery of clean, dry air. The pressure regulator controls the gaging pressure and eliminates surges in air-line pressure which have an effect on gaging accuracy. The restrictor orifice controls the quantity of air flowing in the pneumatic circuit. The back-pressure gage serves as the size-indicating mechanism. The gage head (air jet) directs air flow at the workpiece being measured. The section of the pneumatic gaging circuit between the resistor orifice and the air jet head is frequently known as the *back-pressure chamber.*

The events occurring during an actual gaging operation are diagrammed in Fig. 3. In Fig. 3a, compressed air at a regulated constant pressure flows through the restrictor orifice **A**, through the back-pressure chamber, and out the unrestricted air jet head orifice **B**. Since the cross-sectional area of the restrictor orifice is smaller than the cross-sectional area of the air jet orifice and there is no workpiece to retard the flow of air from the air jet orifice, no appreciable pressure build-up in the back-pressure chamber occurs. This is indicated by no movement taking place on the air gage dial.

The action of the gage when a workpiece is positioned approximately 0.003 in. in front of the air jet orifice is illustrated in Fig. 3b. The position of the workpiece somewhat restricts the free flow of air from the jet orifice. As a result, air is being received by the air jet orifice from the restrictor orifice at a rate faster than it can escape and back pressure starts to build up in the chamber. The back-pressure build-up is indicated by the movement of the pointer on the air gage dial.

The action of back-pressure build-up continues (Fig. 3c), since the restricted volume flow from the air jet orifice has not reached its maximum and air molecules continue to enter the back-pressure chamber faster than they can escape. Hence, the air gage dial still indicates increasing pressure.

Equilibrium is attained when the air molecules escaping from the air jet orifice are equal to the number being received from the restrictor orifice and back-pressure build-up reaches a constant level, as indicated by the air gage dial reading in Fig. 3d.

For all practical purposes, the actions shown in Figs. 3b, 3c, and 3d are instantaneous. Each variation in distance between the workpiece and the air jet head

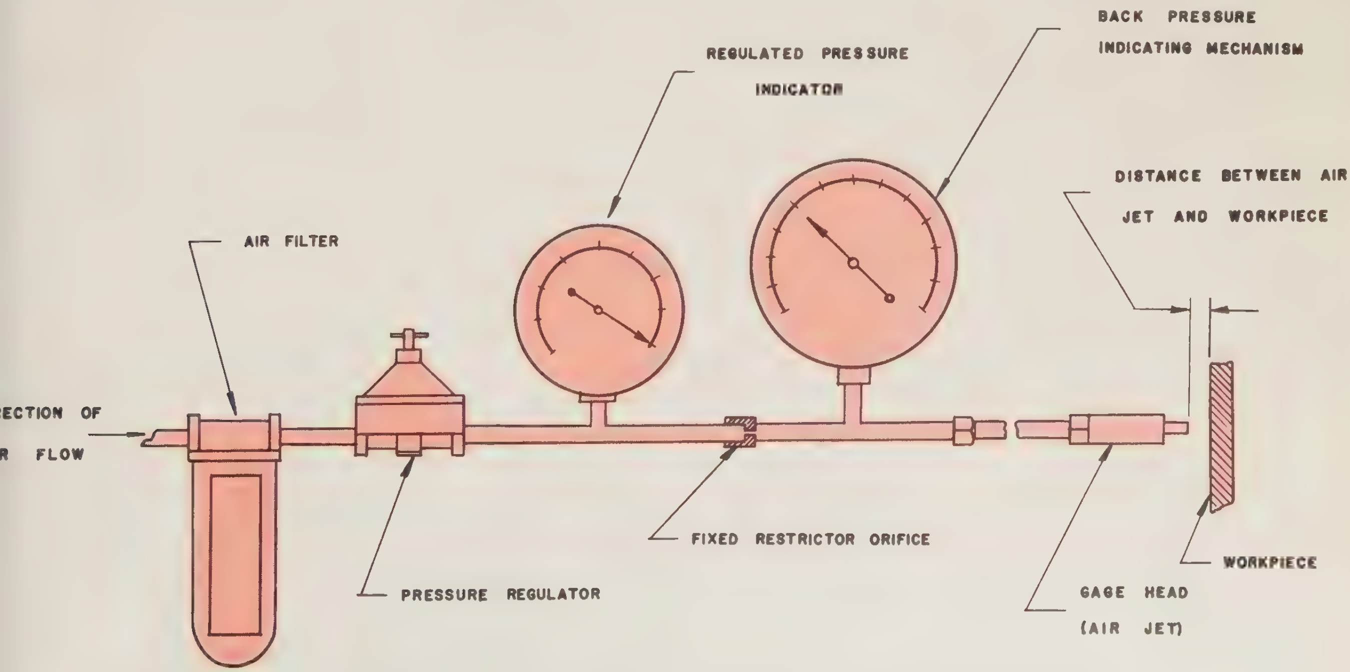


Fig. 2—Schematic diagram of the back-pressure air gage system. The section of the pneumatic gaging circuit between the restrictor orifice and the air-jet head is referred to as the back-pressure chamber.

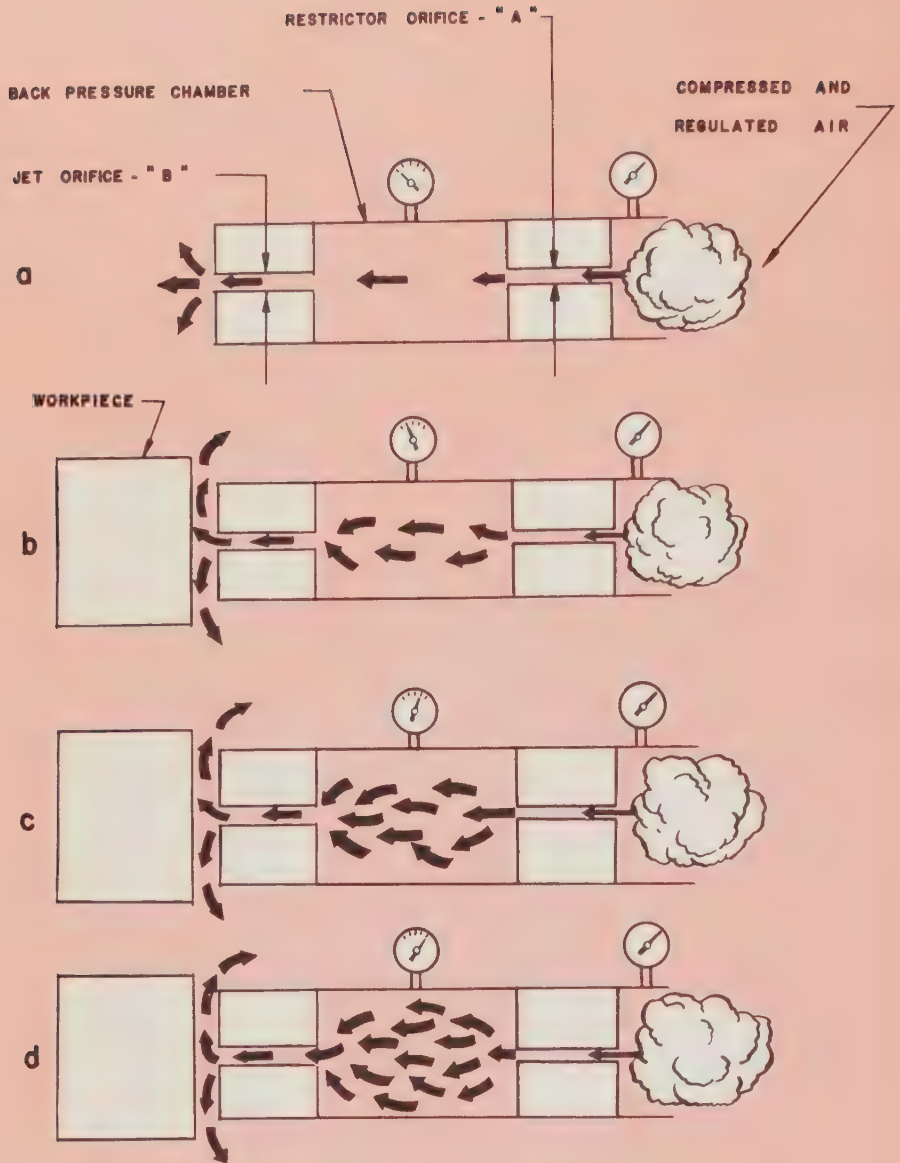


Fig. 3—Events occurring during an air gaging operation. A workpiece positioned in front of the air jet orifice **B** restricts the free flow of air from this orifice. Back pressure starts to build up when the air is received by the air jet orifice from the restrictor orifice **A** at a rate faster than it can escape from the jet orifice. Back-pressure build-up continues until equilibrium is attained when air molecules leaving the air jet orifice equal the number being received from the restrictor orifice. Under equilibrium condition the back pressure, in pounds per square inch, is inversely proportional to the distance, in inches, between the air jet head and the workpiece. Because of this relationship, the air gage dial may be accurately calibrated to show dimensional changes as small as 10 millionths of an inch.

produces a new set of equilibrium conditions, each resulting in a different back-pressure reading. Fortunately, the application of the above principles results in a successful gage because of a definite relationship existing between the gage pressure and the distance from the gage to the workpiece. Established data, based on actual tests, prove that at equilibrium conditions the back pressure, in pounds per square inch, is inversely proportional to the distance, in inches, between the air jet head and the workpiece. The air gage dial, therefore, may be accurately calibrated to show dimensional changes as small as 10 millionths of an inch.

Determing Air-Jet Characteristics

Theoretically, there are an infinite number of jet and restrictor orifice diameter combinations that could be used. In practice, however, it has been found expedient to limit the number of air-jet orifice diameters to those whose characteristics fulfill the requirements of normal gaging applications.

Experience has shown that the following conditions of dimensions and pressure cover the great majority of applications:

- Regulated pressure (25 psi to 60 psi)
- Air-jet orifice diameter (0.031 in., 0.052 in., 0.073 in., 0.094 in.)
- Restrictor orifice diameter (0.013 in. to 0.067 in.)
- Number of air jets in combination (1 to 3).

For practical purposes, restrictors are specified by the drill number size required to form each actual orifice.

Arbitrarily limiting the number of air-jet orifice diameters to four made it possible to set up a program to determine the characteristics of these air jets, each in combination with 30 restrictor orifice sizes. This was done not only for one air jet but also two and three of each size air jet in the pneumatic circuit. The actual program consisted of setting up an apparatus which made it possible to record and plot the back pressure obtained for each 0.0001-in. change in distance of the workpiece from the air jet head.

Air-Jet Characteristic Curves

The program resulted in establishing a family of curves which reliably predict *sensitivity* and extent of *linear range* of gage-head air jets. Two typical curves which illustrate the varying characteristics obtained with different combinations of air-jet and restrictor orifice sizes are shown in Fig. 4.

Linear Range

In the plotting of back pressure as the ordinate and distance of the workpiece from the air jet head as the abscissa, a curve is obtained which changes from concave downward to concave upward (Fig. 5). At the point of transition the slope of the curve reaches a maximum and approaches a straight line. The vertical projection on the horizontal or distance axis of this straight section of the curve is called the *linear range*, since for each change in distance, in inches, of

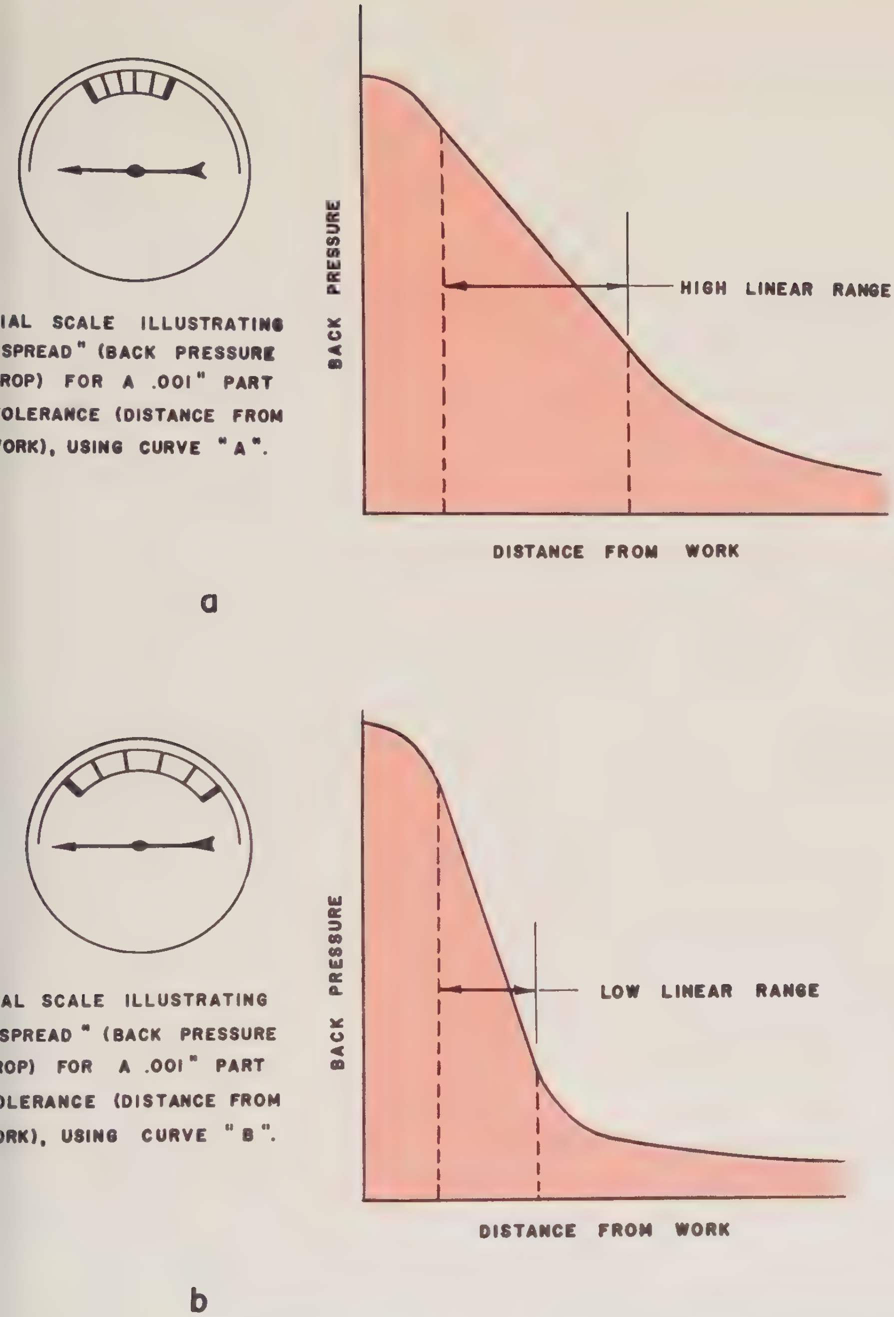


Fig. 4—Different combinations of jet orifices and restrictor orifices result in air gages having varying characteristics. Fig. 4a represents an air gage having a high linear range but a low sensitivity. The low sensitivity is indicated by the relatively short dial scale length which represents the travel of the air gage hand with a 0.001-in. change in distance between the part and the measuring air jet. Fig. 4b represents an air gage having a low linear range and a high sensitivity. The increase in sensitivity over the condition shown in Fig. 4a can readily be discerned by noting the increase in the length of the dial scale which still represents a 0.001-in. change in distance between the part and the measuring air jet. A careful consideration of the balance between linear range and sensitivity is an important factor in the design of every air gage since they are dependent variables.

the workpiece from the air jet head there is an equal change in back pressure, in pounds per square inch. It is this characteristic that permits the precise marking of an air gage dial in equal increments within the end points of the linear range.

Sensitivity

Sensitivity denotes the rate of change of back pressure with change in distance of the workpiece from the air jet head. The greater this change the greater the sensitivity is said to be. With reference to Fig. 5, it can be seen that the sensitivity is determined by the slope of the linear portion of the curve which is equal to the tangent of angle **X**. When the value for the tangent of angle **X** is multiplied by 0.0001 in., sensitivity can be stated in terms of back-pressure drop per 0.0001 in.

The function of air jet characteristic curves is indicated in Fig. 5 which shows one set of three curves out of a family of 90 that cover the use of a 0.031-in. diameter air jet in combination with a No. 77 restrictor (0.0180-in. diameter). These three curves could have been theoretically calculated but experience has shown that for reproducible results and elimination of intangible factors it is best to use empirically determined data. The three curves shown demonstrate the effect of varying the regulated air pressure.

In actual applications, highest sensitivity is usually used only when gaging to very close tolerances since, as shown in Fig. 4b, low linear range is a corollary of high sensitivity. Conversely, gages having a low sensitivity curve are indicated in applications having wide tolerances requiring a long linear range.

Multiple-Jet Circuit Characteristics

The foregoing discussion has been confined to single air jet applications. Many gaging applications utilize multiple jets, which are not discussed further in this paper except to recognize that while their characteristic curves are very similar to those of single air jets, the linear range of multiple air jets is greatly increased in some instances to as much as 0.006 in., as compared to the 0.003 in. for single air jet circuits. These multiple jet circuits are extremely valuable in applications where it is desirable to gage the average diameter of a cylindrical object.

Surface Finish and the Floating Lever

It is logical to suspect that surface finish has a decided effect on size as determined by an air gage. Whereas a standard, solid inside diameter plug gage would show a diameter determined only by the crests of the minute grooves, waves, or scratches caused by various machining operations, an air jet spindle

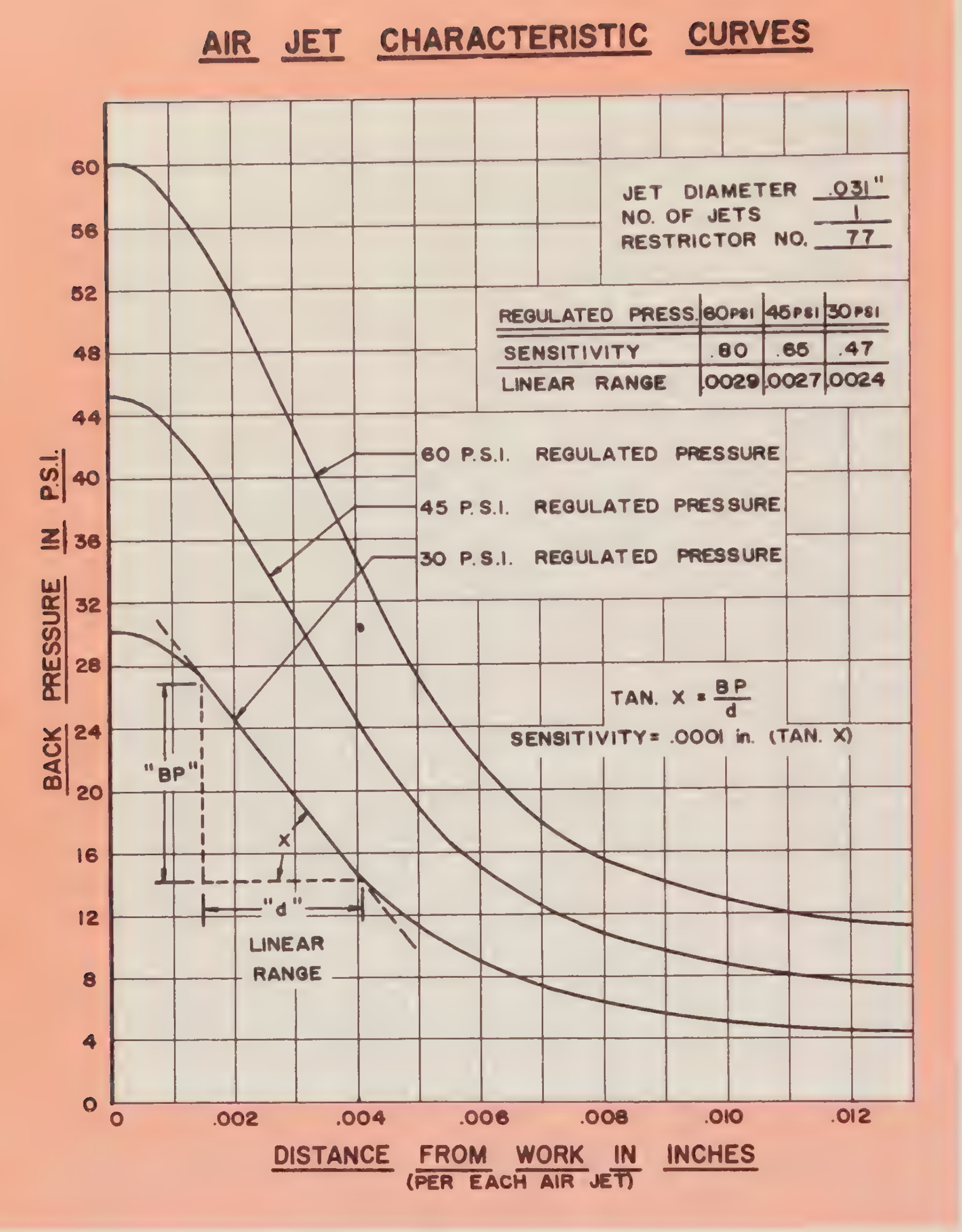


Fig. 5—Air jet characteristic curves indicate the performance of various gages. These curves represent a gage having a single jet, a 0.031-in. diameter air jet, and a No. 77 (0.0180-in. diameter) restrictor. Increasing the regulated air pressure increases the range and sensitivity of the gage. The linear range is found by projecting the straight-line portion of the curve on the horizontal, or distance, axis. The sensitivity, or rate of change of the back pressure with distance from the workpiece, is determined from the slope of the same portion of the curve. Experience has shown that for reproducible results and elimination of intangible factors, it is best to use empirically determined data instead of theoretical calculations when plotting air jet characteristic curves.

would average the hills and valleys and actually show a slightly greater inside diameter than that determined by the standard plug gage. It is for this reason that open air jets are recommended for use only on surfaces having a finish at values of 50 RMS or lower (RMS signifies root mean square—a system for designating surface-roughness height).

To overcome this problem a device known as the *floating lever* was developed some years ago by Delco Products Division (Fig. 6). This simple mechanism utilizes an open air jet in combination with a pivoted lever which actually contacts the surface being measured. The movement of this lever relative to the open air jet is measured by the gaging circuit.

The floating lever also has a secondary advantage—by varying the location of the air jet positions relative to the pivot point it is possible to mechanically extend the linear gaging range to as much as four times that possible with a single, open air jet.

Design Considerations

Air gages can still be built by the old cut-and-try method but designers can achieve far more satisfactory results and savings in time by the use of air jet data and characteristic curves, together with a consideration of the following five points:

- *Type of inspection desired.* Does the job require an actual measurement of each part or is it satisfactory to know that each part is between high and low limits? If actual measurement is desired, the gage dial must have a fairly wide spread which requires a particular selection of jet and restrictor sizes. In general, limit-type gages may be built more economically and have less sensitivity.

- *Type of measurement desired:* two-point diameter check, average-diameter check (three points or more), cloverleaf check, location check, squareness check, depth check, out-of-round check, bellmouth, and hourglass. To meet any of these requirements, the designer must give attention to the position of the part in the gage and the number of jets required.

- *Part tolerance:* sensitivity and linear range requirements. The air jet characteristics for the gage must be selected which will cover the part tolerance with qualification of out-of-tolerance, if required.

- *Surface finish of parts.* If under 50 RMS an open air jet may satisfactorily be used. If over 50 RMS the use of the floating lever pickup is indicated.

- *Anticipated usage.* Is the gage intended for 100 per cent production checking or just an occasional sample inspection? If the gage will have the continual usage of production checking, the designer must provide the ultimate in wear-resistant materials on all contacting surfaces and rugged construction must be used throughout

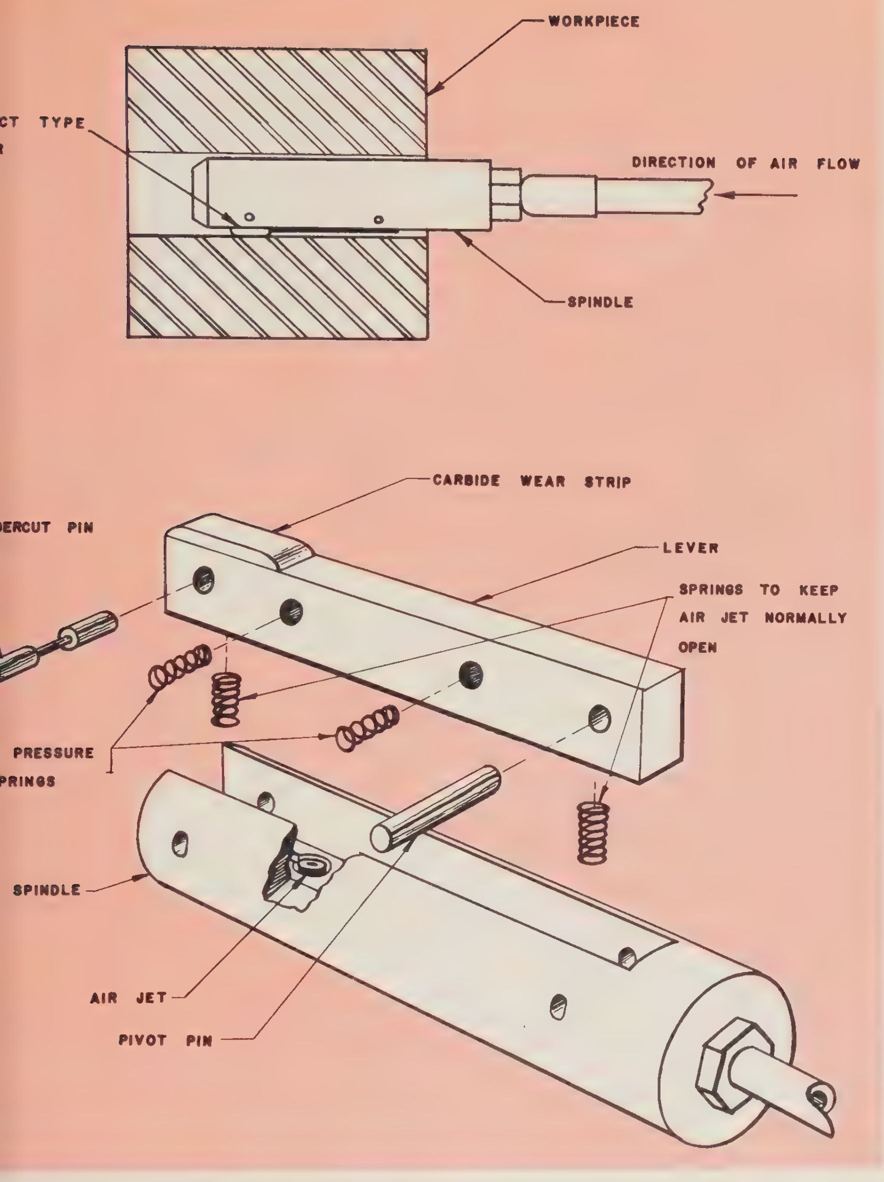


Fig. 6—Floating lever used for accurate air measurement of surfaces having a finish of over 50 RMS. The pivoted lever contacts the surface being measured, and its movement, relative to the open air jet, is measured by the gaging circuit. By varying the location of the air jet position relative to the pivot point of the floating lever, it is possible to extend the linear gaging range to as much as four times that possible with a single, open-air jet. The use of the contact lever is indicated in the upper cross-sectional view.

Summary

There are two factors which place limitations upon the accuracy which can be maintained in measurement by air—dirt and wear in the air-gage pneumatic circuit. If the air supplied is not clean and dry, the air filter functions improperly and passes dirt particles into the air gage circuit. As a result, the restrictor orifice and the air jet orifice become plugged and tend to facilitate erroneous gage readings. Likewise, if the part-locating details of the gaging fixture are allowed to wear beyond reasonable limits, the part-to-jet distance changes to a point where it is no longer within the linear range and inaccurate gage readings result.

In spite of these two limiting factors, the use of air for the checking of precision dimensions in production is still expanding and is generally accepted as being the most economical, trouble-free, and accurate method available for general use in all types of industry—a method which does not require a great deal of operator skill.

Progress Reports from GM Locations

Fastest Firing Jet Aircraft Cannon Now in Mass Production

The fastest-firing automatic weapon ever mass produced is now being built by Pontiac Motor Division under Army Ordnance contract for the Air Force. The new weapon, a jet aircraft cannon officially labeled "Gun, Automatic, 20 MM, M39," was developed to meet the need for split-second volume fire power against fast-moving targets.

The rate of fire of the new weapon has not been disclosed but is acknowledged to be considerably greater than the firing rate of the latest .50 caliber machine gun which fires 1,200 rounds of ammunition per minute. Along with delivering a high cyclic rate of fire power, the weapon is ideal for aerial use due to its relatively light weight.

The new weapon, which is electrically fired and gas-operated, has the appearance of a giant revolver without a hand-grip. Ammunition is carried into the firing chamber in a revolving cylinder. The problem of cooling the weapon is simplified by the revolving-cylinder feature.

Before the weapon was put into mass production, it had been on the drawing boards and in the experimental stage for about five years. During this time many engineering changes were made, mostly for the purpose of lengthening the life of component parts. Some of the changes made were based on experiences obtained by actual use of the weapon in Korean combat.

In addition to the M39 cannon, Pontiac Motor Division holds three other major arms contracts. The Division also builds the Otter tracked amphibious cargo carrier, the 40 mm Bofors-type cannon for tank chassis mounting, and 4.5-in. artillery-type rockets.

Simplifying Problems of Material Identification Through the Development of a Coded Stock Numbering System

By GALEN F. RICHARDS
Inland
Manufacturing
Division

Material groups defined, items readily identified through coded numbers

One of the problems confronting a manufacturing concern is the efficient identification of material items by means other than their physical descriptions. The identification system employed must be both flexible and adaptable to embody all of the materials used directly in the finished product and those used during the manufacturing process. The material identification system must also be one that is able to absorb new material identification brought on by an increase in the range of products manufactured. The system used at Inland Manufacturing Division had proven adequate until the quantity and variety of products manufactured and the attendant increase in materials made it necessary to develop a new system of material identification. This system, which is gradually being put into effect throughout the Division, has facilitated machine accounting and simplified the report procedure applying to material items.

MATERIAL used in manufacturing organizations can be divided into two categories—direct and indirect. *Direct* material is that which becomes a part of the product manufactured, while all other material used by the organization is designated as *indirect* material.

In order to save time and effort in handling information about direct or indirect materials, a material coded-number or lettering system is established so that any item can be identified by a code number or letter instead of by its name and physical description. A coded identification system also serves to avoid confusion in distinguishing similar materials used for the same purpose but not exactly identical in make-up.

The material identification system used by Inland Manufacturing Division, prior to the establishment of the present system, was composed of numbers and combinations of numbers and letters. The system for identifying direct material consisted of six or seven digits and the one for indirect material used from one to five digits. This type of identification proved adequate until the quantity and type of products manufactured—brought about by extensive and continuous laboratory experimentation and development—increased the number of indirect materials used. Consequently, numbers of five digits or less were soon absorbed and positive identification of indirect material became difficult when previously used code identification numbers had to be reassigned to new indirect material items.

It became necessary, therefore, to develop a new indirect material identification system which would meet all forseeable future needs and also reveal the classification and kind of material advantageously and efficiently. The procedure followed in developing the new material identification system included a study of the various components and principles of coded numbering systems, a complete survey and investigation into all the types and quantities of indirect material used by the Division, and a detailed analysis of the numbering identification system then in effect and its attendant problems. The information obtained from this overall study formed the basis for the establishment of the new indirect material identification system.

Objectives and Description of Coded Material Identification Systems in General Use

There are certain objectives which must be met in the establishment of a worth-while material numbering system. These objectives are:

- Positive identification of material
- Flexibility
- Grouping of like material under like numbers
- Adaptation to conform with machine accounting methods.

The first objective, positive identification of material, requires that each item of material have a specific number and that this number be used to identify one particular item only. The second objective, flexibility, requires that allowances be made in the material numbering system which will withstand future expansion in the variety of material numbered or a complete change in the type of products manufactured so that reassigning of previously used numbers to new material items will not become necessary. The objective of grouping like material under like numbers requires that all like material be assigned to one classification or group and a number given to the classification or group which will then become a part of the material's identification number. The remaining objective, that of adapting the system to conform with machine accounting methods, requires that the coding system be as simple as possible and that the material identification numbers be limited to the least number of digits necessary to provide the coded information.

There are several material identification coding systems in common use throughout industry which strive to embody, in some measure, the optimum requirements of the above objectives. In some instances, a system is tailored to a specific application in material numbering and thus cannot be put into general use throughout the plant. Whatever the type of system used, however, it is governed by the amount and type of material to be numbered. Several types of material coding systems will be described in the following discussion with the advantages and disadvantages of each.

A *sequence code* is the simplest form of
oding in use and consists of assigning umbers—starting with the number 1—o a list of items in any desirable order. For example, a sequence code might egin as:

1—barrel bolts
2—carriage bolts
3—chain bolts.

The advantage of the sequence code is ts simplicity and unlimited expansion. The disadvantages of this system are that t is only practical for lists of not more han 50 items and cannot be considered lexible, it makes no provisions for grouping or classification of items, and it is of o aid in accounting machine methods.

A *block code* utilizes groups or blocks of umbers in sequence to represent classiication or groups with the blocks of umbers arranged in any desired numer of units, depending upon the estinated future need for expansion within ny block. For example, numbers 1 hrough 10 identify bolts, 11 through 15 dentify keys, 16 through 23 identify uts, and so on. The block code system rovides for material grouping and is dvantageous only for relatively short ists of material or where the list of mateial to be numbered is definite and roupings remain fixed. The block code ystem, therefore, is flexible only to a imited degree and provides only limited id in accounting machine methods.

The *group classification code* uses the suceeding digits in each material number o represent various classification headngs and the final digit to represent each naterial item. This type of code might egin in the following manner:

2000—supplies
  2100—maintenance supplies
    2110—bolts
      2111—barrel bolts
      2112—carriage bolts
    2120—nuts
      2121—flare nuts
      2122—hex nuts.

This system permits indefinite expansion f provision is made for additions when he original system is established. An stimate must be made of future material o that the necessary expansion is llowed. If this is not done, the amount f material will exceed the limits of each lassification and a new one will need to e established. In this case, two classiications would be used for the same type

F 51 ESTABLISHMENT OF NEW MATERIAL KEY NUMBERS

7598 Present Part No. New Part No. 1521118

CLASSIFICATION BOLTS, NUTS, SCREWS, PINS, KEYS, ETC.

DESCRIPTION Machine Bolt

KIND OF MATERIAL Bolt

FORM OF MATERIAL

STOCK LOCATION (CONTROL) D SUB-LOCATION A and G

UNIT OF MEASURE; PC. X LB. GAL. OTHER

ACCOUNT NO. 77A 77B 77C X 77D 77[illegible] 76 12

SIZE, RATING, OR CAPACITY; 5/8 inch diameter by 4 inches long

MACHINE REPAIR PART; ____ YES X NO. USED EXCLUSIVELY FOR ONE PART ____ YES X NO.

STD., COMMONLY USED; X STD. NOT COMMONLY USED; ____ SPECIAL ____

USED IN DEPARTMENTS; Various

DATE AUTHORIZED FOR STOCK ITEM; 7-11-32

Table I—This sample completed information card contains all the data from which the new material number at the upper right-hand corner is derived.

of material but with widely varying numbers, thus losing the grouping advantage. The group classification code is especially helpful in accounting machine methods as each classification is recognized and controlled by one digit of the material number.

A *significant digit code* uses all or part of the digits in the material number to represent some descriptive factor of the material. Any material items having factors of size, weight, capacity, distance, or rating can be coded in this manner. This code might be arranged as follows:

20000—machine bolts
  20125—⅛-in. diam
  20250—¼-in. diam
  20375—⅜-in. diam.

While this system is a flexible one, it is difficult for the ordinary industrial organization to use since the one code will not suffice for all the variety of materials in stock. It is generally used for relatively short lists of the same type of material. When a significant digit code is used for a long list of widely varying material, the material numbers become long and unwieldy.

A *final digit code* entails the use of significant digits assigned at the end of the material number which may signify any descriptive factor concerning the material. The final digit code is not a complete code and must be used in conjunction with some other coding system. For example, the final digit code can be used with a sequence code as follows:

13—barrel bolts—National Coarse thread
14—barrel bolts—National Fine thread
23—carriage bolts—National Coarse thread
24—carriage bolts—National Fine thread.

The flexibility of the combined codes will be only as good as the parent system. The addition of the final digit code to another coding system usually enables that system to be used efficiently in accounting machine methods as it provides for quicker and more exact sortings of special material indicated by the one final digit of the material number.

Decimal codes use the regular group classification method with the addition of a decimal point and other digits to indicate minor classifications as in the following example:

330—millwright supplies
  331—bolts
    331.1—barrel bolts
    331.11—barrel bolts—special thread
    331.111—barrel bolts—special thread—special head.

The decimal code provides for the addition of any new material by adding

INDIRECT MATERIALS
BY MAJOR CLASSIFICATIONS

No.	Classification Name
10	Abrasives
12	Bearings, seals, packing, and gaskets
13	Belting, belts, hose, cordage, and accessories
15	Bolts, nuts, screws, pins, keys, etc.
18	Chemicals—liquids and gases
20	Dies, punches, and parts
24	Electrical controls, switches, and parts
25	Electrical clips, fuses, lamps, and thermal elements
26	Electrical repair parts and miscellaneous supplies
29	Fuel
33	Hardware and nails
35	Housekeeping and sanitation supplies
38	Insulating material
44	Lacquers, paints, varnishes, and thinners
46	Lubricants and coolants
47	Lubricating equipment, parts, and accessories
49	Lumber, building and construction materials
50	Machine and tool parts
52	Metals—ferrous and non-ferrous
55	Miscellaneous
57	Mold and fixture parts
63	Packing and shipping supplies
66	Plumbing supplies
76	Stationery and office supplies
79	Textiles and fiber
80	Tools—hand-powered
81	Tools—machine-powered
82	Tools—precision
83	Wearing apparel
90	Welding equipment and supplies

Table II—All indirect material used at Inland has been segregated into these 30 representative classifications. Note, however, that the numbers run through 90 to allow room for insertion of additional classifications.

another digit to the right of the decimal point. This sometimes is a disadvantage in that a large addition of new material could demand very large material numbers. For this reason, a decimal coding system is not easily used with accounting machine methods unless the system is converted by removing the decimal point.

Mnemonic symbol codes use letters, symbols, or numbers to describe the material and serve as a memory aid in identification. For example, *BB 1½ NC ¼* might be established to identify a *barrel bolt, 1½-in.* long, *National Coarse* thread, and ¼-in. diameter. The primary disadvantages of this system are that the number of symbols increases correspondingly with the addition of new material items and that it cannot be used in conventional accounting machine methods unless it is converted and each letter and fraction in the material symbol is assigned a number.

A *combination code* is the most common coded numbering system in general use because by combining any of the above mentioned systems the advantages of each may be gained.

The coding system most often used in combination with others is the sequence code, but before determining what coding system best suits the specific condition, all the factors concerning the type and amount of material to be numbered must be thoroughly investigated.

After reviewing the several coding systems available, Inland Manufacturing Division conducted a material item survey to determine which coding system would be best suited to the particular situation at this Division.

Indirect Material Survey

Before a new numbering system could be established, all descriptive information concerning the type and quantity of indirect material had to be obtained with the most important requirement being a concise, accurate description of the material to be numbered. To record the acquired data, material information numbering cards were developed (Table I).

The initial problem in developing the material information numbering card was to determine the extent of information that would be useful for purposes of identification. The major requirement was that all information which might eventually be incorporated in the coded number be recorded. Included in this requirement were the current part number, material description, stock location, unit of measure, inventory account number, and the size, rating, or capacity of the item. All these data were obtained because it would be possible to establish codes for any or all of these items of information.

The next problem in developing the material information numbering card was to determine how much space to allot for information which would be acquired as the code was being built. It was decided that space should be allotted to include the material classification, kind of material, form of material, and new part number. (None of this information was recorded initially but was to be added in the process of building the coded material numbers.)

The remaining card space was allotted to information needed for later reference. This included a note as to whether the material item was a machine repair part, whether it was used exclusively for one part, its average usage, the department where it was used, and the date of authorization of the material as a stock item. These items were to be recorded at the same time as the material descriptions but would not be used until the new numbering system was put into effect. All of the material numbering information, combined and arranged to fit on a 5-in. by 8-in. card, was obtained from stock location records except the new part number, classification, kind of material, and form of material.

Material information numbering cards were first compiled for material carried in the Maintenance Department stockroom and then for material in the Tool Control Department stockroom. To insure accuracy of information, material descriptions were obtained from the departments and checked against catalogue descriptions. Special tool descriptions were obtained from blueprint data along with any additional information that could not be obtained elsewhere. Material descriptions were checked against catalogue descriptions wherever possible. Special items which did not have catalogue descriptions were checked with the Material Control Department to determine the best possible one. The description obtained was the one most commonly used by vendors and purchasers of the material and, while in some cases it was not the one previously used by the Division, the new description enabled better material standardization. After completion, the cards were then filed by part number (currently in effect) for each stock location and maintained in this order until the final system to be used was decided upon.

Coded Numbering System Development

The next step in developing the coded numbering system was to determine the best system to apply from the various systems studied and to prepare an outline based on the information accumu

INDIRECT MATERIALS

BY MATERIAL GROUPS

CLASSIFICATION NUMBER: 52

CLASSIFICATION NAME: Metals—Ferrous and Non-Ferrous

No.	Group Name	No.	Group Name
10	Cold working steel	56	High speed steel—M-2
11	Shafting—steel	57	High speed steel—M-3
12	Tubing—steel	58	High speed steel—M-4
15	Hot-rolled steel	59	High speed steel—M-5
20	Drill rod—water hardening	60	High speed steel—T-1
21	Flat ground stock	61	High speed steel—T-2
22	Tool steel—GM—34M	65	S.A.E. 3135 steel
23	Tool steel—Carpenter No. 11	66	S.A.E. 3140 steel
30	Tool steel—GM—45M	67	S.A.E. 3145 steel
31	Tool steel—GM—44M	68	S.A.E. 4140 steel
32	Tool steel—O. H. Carpenter rods	69	S.A.E. 6150 steel
33	Drill rod—oil hardening	71	N.E. 8640 steel
35	Tool steel—GM—100M	72	Spring steel
40	Tool steel—GM—48M	75	Aluminum
41	Tool steel—GM—102M	80	Copper
45	Tool steel—GM—66M	81	Brass
46	Tool steel—GM—97M	82	Phosphor bronze
47	Tool steel—GM—107M	83	Bearing bronze
50	Hobbing steel	84	Shenango-Penn alloy castings
55	High speed steel—M-1		

Table III—This is one example of the manner in which a classification is partitioned into groups. This partial list of a total of 46 groups has been derived with the greatest number embracing the many different General Motors tool steels used.

lated. In view of the large quantity of materials to be numbered, it was decided that a combination code, consisting of a group classification and a sequence code, would best apply to the particular situation at Inland Manufacturing Division and also meet the four objectives of a good material coding system.

Indirect Material Segregation and Classification

The first step in setting up the code was to establish the material classification and this was accomplished separately for each stock location. First, all maintenance material was segregated into the various maintenance sections, for example, electrical, plumbing, and welding. The material common to all trades was then grouped, leaving all other material in groups according to trade. Each of these groups was then assigned a classification name.

The next stock material segregated was for the Tool Control Department. This material was first divided into five sections—tools, raw metal supplies, machine and tool parts, die and punch parts, and mold and fixture parts. All tools were then divided into three additional sections—hand-powered, machine-powered, and precision tools—and each of these sections given a classification name.

All other material was then assigned to these classifications wherever possible. The materials remaining were surveyed for similarity of use and all material that was used for the same purpose was grouped and assigned a classification name. For example, all material that was used for an abrasive purpose—such as cutting or scratching—was grouped and the classification name *abrasives* assigned. This method of segregation was used for all indirect material until it had been completely classified. Table II shows the resulting major classifications for indirect materials.

The next step was to assign each material item to its appropriate classification. This was done by inspecting each indirect material description and writing the appropriate classification name in the allotted space on the material information numbering card. All the material cards were then sorted by classification name.

Material groups was the next division established. This was formed by sorting all identical material from one classification and grouping it under one heading which was then established as the group name. For example, all hot-rolled steels in the *Metals—Ferrous and Non-Ferrous Classification* (*No. 52*) were grouped and assigned the name *hot-rolled steel*. In the majority of cases, the only difference in the material in each group was the size. The proper group name was then noted on each material card and the cards sorted by group name under each classification. Table III shows a portion of the material groups for the Metals—Ferrous and Non-Ferrous Classification.

It was then necessary to arrange all the cards in the proper sequence. First, all *classifications* were arranged in alphabetical order by classification name. Next, all *groups* under each classification were arranged in alphabetical order by group name. Finally, each indirect material item in each group was arranged either by alphabetical or size sequence, whichever arrangement was the most logical. Table IV shows an example of this type of arrangement. This completed the establishment of indirect material classifications and groups in the most logical arrangement.

Assignment of Material Numbers

The next step was to assign identifying numbers to the various classifications, groups, and indirect material items.

ALPHABETICAL SEQUENCE	
Classification: Housekeeping and Sanitation Supplies	
Group:	Brooms
Items:	Fiber factory broom
	Fiber street broom—with handle
	Office broom—straw
	Push broom
	Whisk broom

SIZE SEQUENCE	
Classification: Bolts, Nuts, Screws, Pins, Keys, etc.	
Group:	Fasteners—Corrugated
Items:	Fasteners—
	corrugated—0.125 by 4 in.
	corrugated—0.250 by 4 in.
	corrugated—0.375 by 4 in.
	corrugated—0.500 by 4 in.

Table IV—Individual items within each group may be arranged in sequence alphabetically (left) or according to size (right), whichever proves the more beneficial arrangement.

Because there were more than nine classifications, two digit numbers had to be used for each classification. The first number assigned was 10 so that each material classification number would contain the same number of digits. Numbers less than 10, preceded by a zero, could have been assigned but there would be a tendency to drop the zero and write only the first whole number. This would hinder accounting machine methods which require material numbers to contain the same amount of digits for the most efficiency.

Classification numbers were not assigned in numerical sequence in order to allow space for the insertion of new classifications in the proper alphabetical order and their accompanying numbers into the correct numerical sequence. Because of this fact, the initial classification numbers spread from 10 to 90 with 70 numbers not being used. Numbers were assigned to each list of group names in the same manner, with the first number used being 10 and a similar spread in numbers being maintained.

Before assigning material item numbers, the classification and group numbers were written on the material information numbering cards in the designated space (Table I). The classification number was recorded first since this would constitute the first two digits of the new material number. Following this, the proper group number was written on each card after the classification number. Thus, these two digits constituted the third and fourth digits of the new material number. In assigning material item numbers, three digits were used for each item and then assigned to each card, spreading the numbers from 001 to 999 so that new items could be inserted in their proper place. These numbers were written after the group numbers to produce a seven digit material number for each material item. This completed the assigning of new material numbers and the material cards were thus arranged in new material number order.

Finalized Code Numbering System

The final code structure based on a combination of the group, the classification, and the sequence codes to indicate classifications, groups, and items, was established as follows:

```
1  2  3  4  5  6  7  —number of digits
                       in code
(X X)                —classification
      (X X)          —group
            (X X X)—item.
```

The overall survey, when completed, divided all indirect material items at Inland Manufacturing Division, numbering approximately ten thousand, into 30 classifications. As an overall group, the allowance for future expansion in the type and quantity of materials used is great enough to meet all anticipated requirements and each classification will be general enough to identify materials having general similarities. If it becomes necessary to add more precise classifications, ample space is provided. By using two digits in each classification number, a maximum total of 100 numbers (with the use of 00) is available. This leaves an additional 70 classifications that could be established. At the present ratio, this means that over 20,000 new indirect material items could be numbered by this system without altering the number of digits in the material number.

Maintaining the System

In order to keep the coded numbering system current, worksheets have been prepared which list all the indirect material item numbers from 001 to 999. Separate sheets are made for each group with the classification noted. Each material item number, as it is used, is crossed off the sheet and if the material item becomes obsolete it is then circled to indicate that the number is again available for use. If the number is then reassigned to some new material item, it is again crossed off the sheet to avoid duplication.

A card file also has been set up for each material item, listing its description, former part number, and new coded number. In case a material item becomes obsolete, the item's card is removed to an obsolete file so that it will be available if the material again becomes active.

Applying the Coded Numbering System

In order to properly apply the new system, a catalogue of all indirect stock material with the description, former part number, and new coded number is required. Table V shows a sample page of the catalogue. In addition to the catalogue, an information booklet is also available which lists the following data:

(a) General information
(b) Catalogue use
(c) Procedure for revising catalogue
(d) List of classifications
(e) List of groups.

The first section—general information—contains a clear statement of the purpose for establishing the new system as well as an explanation of the type of code used and the significance of each set of digits in the material number. A sample application of the code to a material item is presented with an explanation, and the catalogue's distribution channels established.

The second section—use of the catalogue—explains how to apply it, pointing out when the coded material numbers are to be used, and refers to the list of classifications and groups, explaining how to locate material items in either list.

The third section—methods of revising the catalogue—designates the department or section to be responsible for maintaining the catalogue. It also explains the procedure for adding new material items, obsoleting old ones, and the method of issuing catalogue supplements.

The fourth and fifth sections—the lists of classifications and groups—have been incorporated for reference purposes. This enables anyone using the catalogue to

termine in what class and group to cate material as well as obtain the st four digits in the material number. The indirect material catalogue and companying procedures booklet were stributed to all stockrooms, receiving cations, tool cribs, maintenance offices, d purchasing and accounting sections ncerned. Each of these organizations sumes responsibility for keeping its talogue up-to-date and inserting the cessary supplements.

Schedule for Establishing the System

After the new coded numbering system d been developed, a decision had to be ade as to the most practicable time to t the system into effect. It was decided at the system would be established in ch individual stock location as the mbers for that location were com-eted. All material needed for the sys-m was prepared previously, catalogues d booklets distributed, departmental sponsibilities in maintaining the system signed, and orientation meetings held. or accounting purposes, cards were pre-red to include the new coded material mber. On a given day, the new system as placed into effect with all material in at particular location being identified the new coded material number only. eference to the old numbers was then ed for the sole purpose of locating old cords pertaining to the material.

Summary

The newly developed coded number-g system assigned new numbers to each m of indirect material and provided for:

- Grouping of all material of identical nature under like headings in either alphabetical or size sequence
- Provision for the addition of new materials or a complete change in type of material used
- Maximum use of all available numbers.

om the capacity standpoint, this sys-n will allow for numbering all future direct materials to be used at Inland anufacturing Division, at the present te of expansion. The positive identifi-tion of material characteristics achieved th the new coded numbering system events unnecessary stocks of identical aterials, enables closer control of obso-e items, saves time in accounting pro-dures, and conserves time in locating aterial.

MAJOR CLASSIFICATION #52 Page -13-

New Part No.	Description	Size	Old Part No.
5235145	Tool Steel - GM-100M	2" Dia. x 12 Ft.	25-1369
5235161	do	3" Dia. x 12 Ft.	25-1371
5235169	do	3-1/2" Dia. x Various Lengths	25-1396
5235521	do	1/2" x 1" x 12 Ft. Max.	25-1358
5235523	do	1/2" x 1-1/4" x 12 Ft. Max.	25-1378
5235525	do	1/2" x 1-1/2" x 12 Ft. Max.	25-1359
5235528	do	1/2" x 2" x 12 Ft. Max.	25-1360
5235530	do	1/2" x 2-1/2" x 12 Ft. Max.	25-1361
5235635	do	1" x 3"	25-1362
5235660	do	1-1/4" x 2" x 12 Ft. Max.	25-1401
5235709	do	2" x 3" x Various Lengths	25-1429
5235711	do	2" x 4" x Various Lengths	25-1363
5235734	do	3" x 6" x Various Lengths	25-1364
5240113	Tools Steel - GM-48M	1/2" Dia. x 12 Ft. Max.	25-1477
5240120	do	3/4" Dia. x 12 Ft. Max.	25-1478
5240129	Cromovan Steel GM-48M	1" Dia.	25-1051
5240137	Tool Steel - GM-48M	1-1/2" x Various Lengths	25-1050
5240145	do	2" Dia. x Various Lengths	25-1508
5240153	do	2-1/2" Dia. x Various Lengths	25-1509
5240161	do	3" Dia. x Various Lengths	25-1052
5240681	Cromovan Steel-GM-48M	1-1/2" Dia. x 2-1/2"	25-1008
5240683	Tool Steel - GM-48M	1-1/2" x 3" x Various Lengths	25-1107
5240706	do	2" x 2-1/4"	25-1009
5240727	do	2-1/2" x 3-1/2" x Various Lengths	25-1472
5241120	Tool Steel GM-102M	3/4" Dia.	25-901
5241161	Ludlum Huron Steel GM-102M	3" Dia.	25-397
5245129	Chisel Steel GM-66M	1" Dia. x 12 Ft.	25-1291
5245131	Tool Steel GM-66M	1-1/8" Dia. x 12 Ft. Max.	25-1370
5245133	do	1-1/4" Dia.	25-1403
5245135	do	1-3/8" Dia. x 12 Ft. Max.	25-1495
5245137	do	1-1/2" Dia. x 12 Ft. Max.	25-1496
5245139	do	1-5/8" Dia. x 12 Ft. Max.	25-1497
5245141	do	1-3/4" Dia. x 12 Ft. Max.	25-1357
5245678	do	1-1/2" x 1-3/4" x 12 Ft. Max.	25-1372
5245735	Chisel Steel GM-66M	9-3/16" x 3-1/8" x 32"	25-999
5245901	Tool Steel GM-66M	3/8" Octagon x 12 Ft. Max.	25-1462
5245902	do	1/2" Octagon x 12 Ft. Max.	25-1463
5245903	do	5/8" Octagon x 12 Ft. Max.	25-1464

Table V—A sample page taken from the Inland Material Number Code Book illustrates the range of data used in establishing the system. The major classification number is shown in the upper left hand corner for quick reference purposes and the old part number listed for reference to old records concerning the material.

Bibliography

Other related literature in this field includes the following:

Buhl, William F., "Codes for Materials," *Factory Management and Maintenance*, Vol. 102, No. 5 (May 1944), pp. 110-112; No. 6 (June 1944), pp. 126-28.

Smith, N. L., "Better Identification of Expense Materials Through Mnemonic-Numeric Coding," *N.A.C.A. Bulletin*, Vol. 31, No. 6 (February 1950), pp. 749-54.

......, "For Better Stock Control: Remington Rand's Commodity Classification Department," *Standardization*, Vol. 21, No. 2 (February 1950), pp. 29-31.

......, "Stopping Stock Duplication: Remington Rand's Commodity Classification Service," *Business Week*, No. 1048 (October 1, 1949), p. 32.

Atkins, Paul M., *Factory Management* (New York: Prentice-Hall, Inc., 1926), pp. 219-29.

A Challenge for Today's and Tomorrow's Engineers—Making a Life in Technical Industry*

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Much of the progress of industry in the past half-century has depended upon the successful application of engineering skill. Therefore, industry is concerned with the favorable adjustment of the graduate engineer to industry. If such an adjustment is to be made, it calls for the sincere cooperation of engineering education, the technical societies, and industry itself. Most important, however, it depends upon the display of a wholesome attitude on the part of the engineering graduate.

On attitude: One candle in the dark can shed its light a great distance

TODAY, across the country thousands of future engineers are in the midst of a year of study and training for their future profession. Thousands more have only recently been graduated and are in industrial training programs or are just getting started on the job. These engineers and engineers-to-be are ambitious young men who want to get ahead and industry wants to see them get ahead.

The early years in industry are very important for the young engineer because in these years much of the adjustment from the college scene to the industrial scene must be made. In making this adjustment many of his attitudes are molded. Industry wants to create a favorable climate for the young engineer so that the individual will want to consider his work as an opportunity to develop and to express his latent talents rather than merely an economic drudgery, necessary to make a living. The individual engineer needs to come to the realization that his attitude toward work, toward living, and toward people will develop an inner satisfaction through personal attainment—attainment which is measured directly by the elastic limit of his abilities.

Attitude Is the Key

The attitudes of a person affect so very strongly his actions. Success is associated with great actions, whether they be sudden as in battle or on an athletic field or sustained over a lifetime as in the case of great statesmen. Men who translate their lives into great actions invariably exhibit wholesome attitudes.

Somewhere down through life each person is attracted by some men of action, and invariably he admires these men for some personal traits. These traits may include ambition, cheerfulness, confidence, courage, enthusiasm, integrity, loyalty, perseverence, self-control, understanding, vision, or others. Notice how each is an attitude.

Each of these traits associated with success is the expression of a wholesome attitude toward people, toward work, or toward living in general. Here in the United States all are free to assume or develop any or all of these traits. Similarly, experienced engineers and educators are free to demonstrate a willingness to instill and develop these traits in the young men who come within the shadow of their influence.

This shadow of influence is often longer than it is recognized to be. In many ways, the founding fathers of this country considered themselves as very ordinary folks and yet one has only to look about him to see the far-reaching results of their sound thinking. The nation's well-known material advantages are but a part of the visible benefits.

Suppose for a moment that the founding fathers of this country had set up a government such as that which has grown up behind the Iron Curtain. Could the same material advancement have been possible, even with this country's vast natural resources at their disposal? History's pages are full of examples of nations which had the same material opportunity to prosper as had the United States but somehow did not achieve the same benefits.

Certainly, undue importance should not be placed on our material advantages, nor is anything American necessarily the best in the world. However the working climate of individual initiative which made our high standard of living possible is most valuable and i

Fig. 1—The annual General Motors Conference for Engineering Educators, sponsored by the Engineering and Manufacturing Staffs, exemplifies industry's desire to exchange viewpoints with colleges and universities. Engineering educators who participated in the 1954 Conference were: (left to right) Raymond Cohen (Purdue University), William E. Reaser (Princeton University), Paul G. Hausman (University of Kansas), James L. Leach (University of Illinois), Hugh G. Conn (Queen's University), Wallace J. Richardson (Lehigh University), L. V. Colwell (University of Michigan), Harold T. Amrin (Purdue University), Gordon E. Rivers (Wayne University), Robert S. Jones (Wayne University), John M. MacKenzie (University of Minnesota), Allen H. Spinner (Stevens Institute of Technology

*Adapted by the author from "Experience Tells Me," a talk given at the 1954 College Industry Conference of the Relations with Industry Division, American Society for Engineering Education, held in Detroit and material from other recent talks.

orthy of highest endorsement.

The young engineers of this country, ong with all its people, still live under e shadow of the influence of its foundg fathers. This freedom gives them the ght to life, liberty, and the pursuit of appiness according to their own attides toward these three elements. They e free to demonstrate, to live, and to xpress their attitudes toward good or vil objectives—and their attitudes can e very contagious.

A wholesome attitude underlies sucss in any venture and this nation is one which a wholesome attitude pays off r all. Industry, engineering educators, nd members of technical societies all eed to try to apply such a wholesome ttitude to the task of creating the right nd of climate for the young engineer in is early years in industry realizing, of ourse, that the young engineer by his ork and attitudes must bear full responbility for taking advantage of the opporunities available in this climate.

Industry and Education

In the area of education, first of all, onest recognition should be given to the ore of technical knowledge which the oung man has gained on earning his accalaureate degree in engineering.

When engineering graduates come into ndustry, industry assumes responsibility f carrying on where engineering eduators have left off. While industry welomes and seeks young engineers, it ecognizes that engineering graduates re by no means finished products. Engieering educators have trained them to ecome engineers, and were not expected o turn out these young men as finished engineers. Today's technology is far too complex to expect of any young man that he step into a full-scale engineering job without further training by and in industry. The responsibility of undertaking this further training program is one which industry gladly accepts.

In such industrial training programs, experienced engineers have an excellent opportunity to discuss the value of graduate study as it might apply to each individual and, in some cases, to recommend to the young engineer that he supplement his on-the-job training with formal graduate study. Among the means taken by many industries to promote the self-development of young engineers through graduate study programs are:

- Reimbursement of tuition, provided certain requirements are met
- Granting of graduate scholarships to employes
- Granting to colleges and universities graduate fellowships which are filled by students who do not commit themselves to become employes of the industry which makes the grant.

Industry also promotes a closer liaison between engineering education and their employes through:

- Bringing engineering professors into their laboratories and plants for summer work
- Conducting seminars in which professors are invited in as leaders
- Conducting conferences in which engineering educators are invited to a program of visits and lectures to better acquaint them with industry's viewpoints and to bring to industry a greater understanding of problems in engineering education (Fig. 1)
- Sharing technical information (Fig. 2).

ohn H. Dittfach (University of Massachusetts), Irvin P. Hooper (Rose Polytechnic Institute), Charles A. ilpin (University of Wisconsin), J. S. Campbell (Queen's University), James A. Gage (University of Visconsin), Robert D. Strum (Rose Polytechnic Institute), Thomas E. Jackson (Lehigh University), ugene F. Hebrank (University of Illinois), John H. Kuhlmann (University of Minnesota), Horace W. eet (University of Rochester), Thomas R. Faucett (University of Rochester), Kenneth E. Rose (Uniersity of Kansas), Augustus R. Rogowski (Massachusetts Institute of Technology), Merle L. DeMoss General Motors Institute), (absent) Edward A. Reed (General Motors Institute).

During conferences for engineering educators held annually by General Motors, it has been demonstrated that the educators are divided into two academic camps. One group feels that industry has grown so complex that it is no longer possible to specialize engineering education to a sufficient degree that the graduate will be immediately profitable to industry. This group urges a return—or a continuing emphasis—on a thorough grounding in the basic sciences. The second group feels that a student ought to be trained very thoroughly in a narrow technical field so that he can be immediately valuable in his specialty. The educators at each conference appoint a spokesman from their number to summarize their findings. Here is what one Professor, from the University of Toronto, had to say in his talk given near the end of a 15-day conference:

> This question on whether a narrow or broad education is preferred was asked of the officers of General Motors, both in this room the week before last and by most of us at our Divisional assignments. The answer was quite unequivocal and a bit shocking.
>
> General Motors, judged by the composite answers, did not fall into the arms of either camp but marched bravely to a third position, stuck its banner in the ground and allowed us to see on it words emblazoned in letters of gold, and we looked at one another, for those words didn't appear in the syllabus, the curriculum of either camp, and these words were thus strange to us. They were principally integrity, diligence, ability to express one's self, and one or two other qualities.

Apparently, the Professor from Toronto used the word *shocking* to heighten his meaning. By his actions during the two weeks he was a guest at the conference,

Fig. 2—Another medium through which industry and engineering education may meet is a common sharing of information made possible by engineers in industry speaking before student groups on campuses. In this manner, engineering students may come to appreciate the methods by which industry solves its engineering problems.

he stood out as one who in his associations with students would definitely generate just the kind of wholesome attitudes in students which industry desires. When the student becomes employed, industry desires not only that the employe make his contribution to industry but, more importantly, that he may make life satisfying for himself and for his family.

The desire on the part of General Motors for favorable attitudes transcends any preferences which they might have with respect to curricula, whether they be specialized or stress the basic sciences. It means that in the eyes of industry all young people ought to be far more conscious of the ultimate objectives of all education and training—namely becoming equipped to make a satisfactory living, but more importantly to make a successful life.

Dr. Kenneth MacFarland, former superintendent of schools in Topeka, Kansas, has made a study of why people fail at jobs. He reported that only 10 per cent failed through lack of skill or ability. The remaining 90 per cent failed because of laziness, poor health, bad personal traits, dishonesty, immorality, disloyalty, and kindred causes. Here then is the challenge demonstrated. The 10 per cent failure through lack of skill or ability indicates a job well done by the educators in the area of supplying the necessary facts, although that 10 per cent can be a strong minority. On the other hand, each of the causes of the 90 per cent failures, with the exception of poor health, are attributable either to a wrong attitude toward work, life, or people. Certainly, the college years are very impressionable ones for the future engineer. Professors and instructors have a superlative opportunity while indoctrinating their students in engineering knowledge to instill also the less easily defined fundamentals of effective living. In this latter task, the best teaching tool is the power of example.

Technical Societies

In the joint effort which is necessary if a proper growing climate is to be provided the graduating engineer, technical societies also occupy an important place. These societies have their opportunity to demonstrate to the young engineer the value of effective living as an engineer, for these societies offer a medium whereby the young engineer can obtain a broader viewpoint of his particular specialty. His society membership gives him the opportunity to hear the viewpoints of a broad cross section of engineers in his own field and to learn from their experiences.

The technical societies might we profit by making sure that their young members have an opportunity to discu with older members informally and qui frequently their areas of mutual interes The society should do this as a prima job, for it is quite easy for a young eng neer to gain precisely the kind of techn cal information heard in lectures simp by visiting a good technical library. Ar society also has the opportunity throug its membership to disseminate inform tion on the technique of effective livin And since it is a society, it also mu offer some social outlet to its membe ship. This enables the older members set the same kind of good example whic professors can set in their classrooms.

Industry and the Individual

Just as the responsibilities of enginee ing education and industry interming so do those of industry and the in vidual. As stated before, engineeri educators train and develop a young m to become an engineer and industry h the responsibility of creating a climate which the graduate can express th training in work. His profession must be permitted to lapse into a simple tr wherein his productiveness would measured purely by the hours spent the job (though this is necessary) rat than by his creativeness as a member a proud profession.

Industry's responsibility, then, is create a proper climate for creative en neering. The employer needs to have d regard for the worth of an engineeri education. He needs to assure hims that the young engineer gets as profitab experience and training during his fi years in industry as does the medi school graduate during his internshi Further, he needs to establish and maintain equitable policies and pra tices relating to salaries and promotio so that the young engineer will have t benefit of personal rewards commens rate with his ability to translate his en neering knowledge into work for the su cess of both the business and hims Industry does not automatically prom its employes; always, it is a case of employe creating an opportunity for pr motion for himself by his own work a by his own vision.

On-the-job training is necessary but must necessarily be of a short-ran nature in order for industry to get

anifold technical tasks done according existing and changing procedures. here is only limited time available for ndamental technical study except as ch study might come on the job while e engineer is producing (Fig. 3). Em-oyers would find little success in requir-g their young graduates to continue in ght school until they obtained ad-nced degrees. That step, too, is left to e individual initiative of the young gineer. He must sense the advantage further formal education to equip him r making a greater contribution to his mpany. From a practical standpoint, dustry could hardly arbitrarily set wn practices which would guarantee ogress purely on the ground of em-oyes obtaining advanced degrees.

The young engineer has a grave sponsibility in his own self-develop-ent. He needs to find his own definition successful living and a way to derive e maximum benefit from both his tech-cal education and his ability to work as member of a team—to lean on his col-agues and to serve them at the same me. His attitude toward them and ward his work will determine his own ccess in developing his abilities to their astic limit. In the final analysis, the oung engineer himself has the responsi-lity for his own self-improvement.

While the young engineer might well now what the ideal working and learn-g climate is, he will not find it exem-ified perfectly anywhere in industry, llege, or technical society. The young gineer then needs to adjust his own inking to the situation as he finds it d to try to improve the situation and mself within the framework which he nds. One thing is certain, a wholesome titude in each new engineer in any boratory is a force to the good. One ndle in the dark can shed its light a eat distance; so the new engineer is pable of being a strong influence in eating the right kind of atmosphere in aces where it did not exist before his rival.

Conclusion

While this is an age of opportunity, it also an age of responsibility and com-tition. Engineering education has the sponsibility of creating a learning at-osphere which is wholesome. It needs offer courses which are of value and terest to young engineers. Further, here possible, graduate courses need to be brought geographically near to places where young engineers work so that they can benefit from them and still meet their own work schedules.

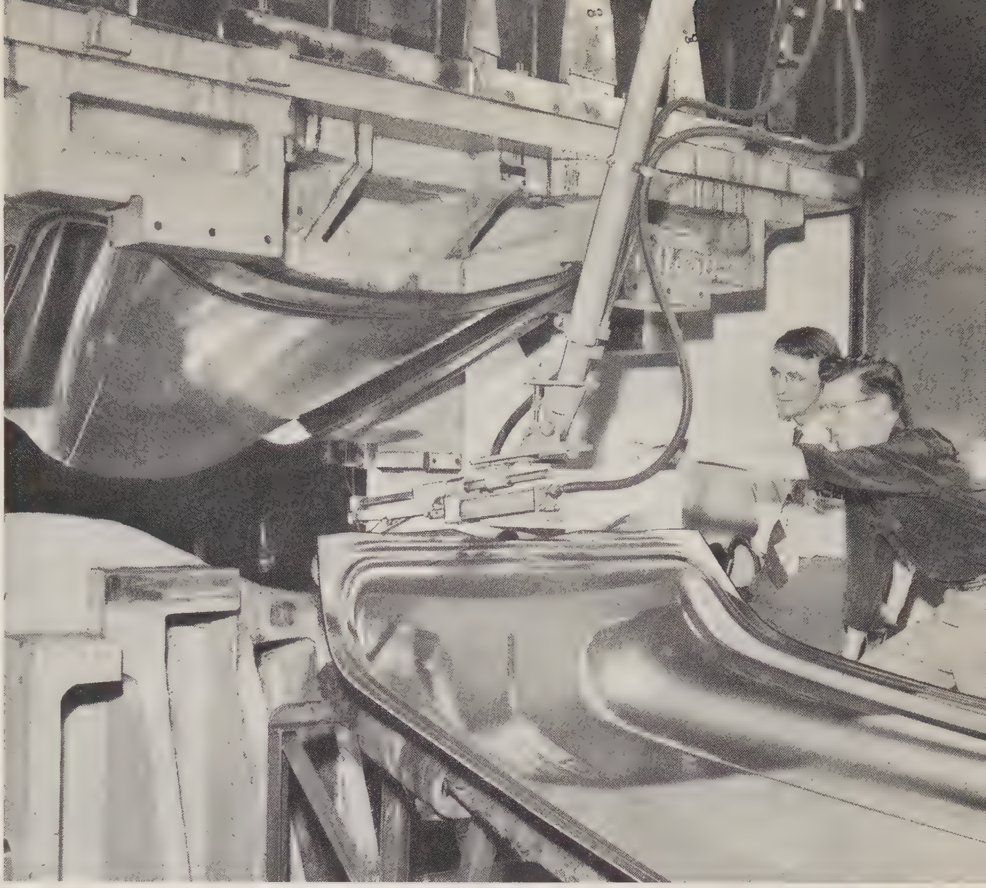


Fig. 3—The young engineer's education does not finish with the receipt of his baccalaureate degree in engineering. Once he is employed by industry, he receives specific on-the-job training to prepare him to use most advantageously the fundamental technical knowledge he has learned in the classroom. This scene shows a young engineer at work at Buick Motor Division being assisted by an experienced engineer.

Technical societies are in competition with many interests for the time of young engineers. No society can long exist or make a contribution to its profession without developing a strong young mem-bership. And a young membership can-not be developed unless there is a pro-gram for the full year which will make new members feel that they benefit tech-nically and otherwise by participation.

Industry has a three-fold responsibility which it must bear gladly because of its opportunity to derive productive effort from engineering graduates. Industry needs to cooperate in the actual process of education so far as good business prac-tice can permit. It must be helpful with-out interfering with the patterns which engineering colleges have developed so well. By creating the right kind of work-ing climate in every respect, industry can fulfill its second responsibility of helping engineering graduates make the transi-tion from the rather carefully directed and formal learning environment of the classroom to industry. Then he can effec-tively continue his own self-development to the point where he becomes capable of directing his own efforts with a mini-mum of supervision. Thirdly, industry must maintain a working atmosphere for all of its engineers which will enable them to reach their highest status as engineers.

In summary, the entire program of helping to make the early years of the engineer in industry successful is a joint effort. However, in the final analysis, en-gineering education, technical societies, and industry can serve only to assist the young engineer in his own development —to point the way. The sole responsi-bility for assuming and developing right attitudes toward work, toward people, and toward living rests squarely on the shoulders of the young engineer. And he will find that hard work on his part has a dignity about it and is the key to his suc-cess not only in his early years in indus-try but in all the years to follow.

General Motors Test 20—A New Standard Means for Determining Gross Horsepower

By RALPH A. RICHARDSON,*
Secretary
Engine Test Code Subcommittee
General Technical Committee

Horsepower figures have more meaning when standard test conditions are specified

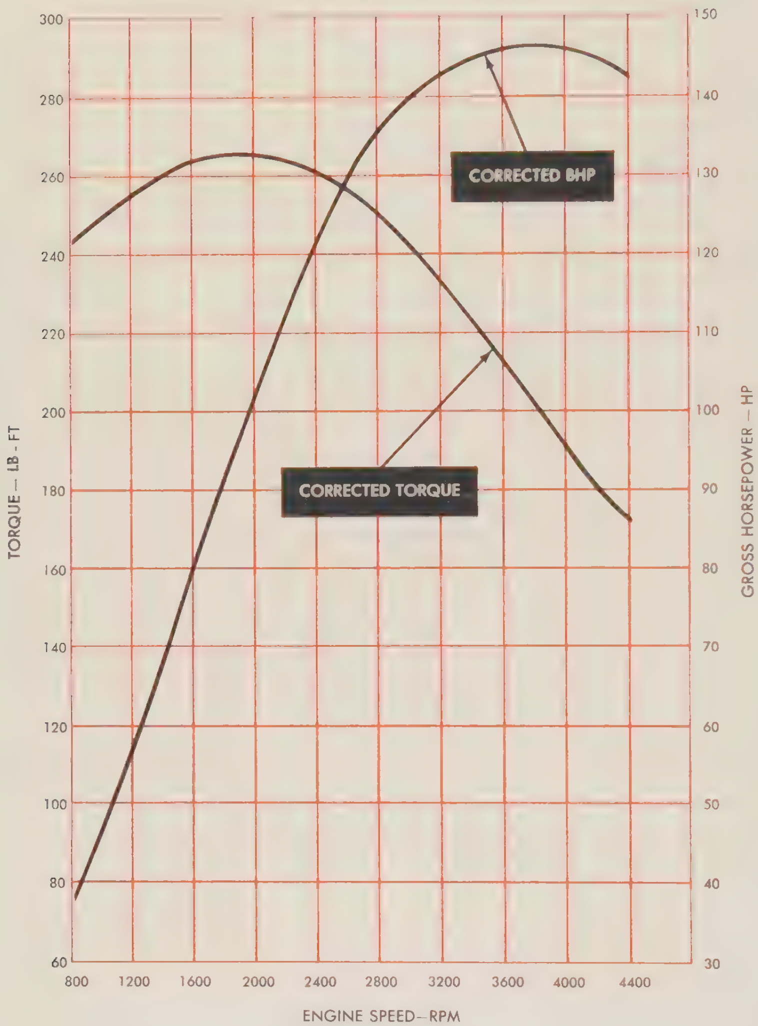


Fig. 1—These typical corrected gross brake horsepower and torque curves were extracted from the sample curves in the supplement to the fourth edition of the General Motors Automotive Engine Test Code. The engine test data, taken at intervals of 200 rpm from 800 rpm to 4,400 rpm, were corrected to 60° F and a standard dry air pressure of 29.92-in. Hg, according to a Society of Automotive Engineers correction factor. Here, the advertised maximum horsepower would be 147, reached at 3,700 rpm, and the maximum torque would be 266 lb-ft, recorded at 1,800 rpm.

In the March-April 1954 issue of the General Motors Engineering Journal an announcement was made o the fourth edition of the General Motors Automotive Engine Test Code. This code describes test procedures for numerous tests used in the engineering departments of General Motors for evaluating engines. Since the announcement was published an additional procedure has been ap- proved by the Engineering Policy Com- mittee, General Technical Committee and Engine Test Code Subcommittee fo inclusion in the Code. This has bee titled "Test 20—Gross Engine Horse power." Test 20 will be used by al General Motors Divisions to obtain th values for advertised maximum horse power and torque.

The new gross engine horsepower tes provides a uniform procedure for obtain ing the maximum power and torque of a bare engine. This eliminates the influ ence of such engine accessories as the ai cleaner, muffler, exhaust heat to th manifold, and exhaust manifold hea

* For portrait and biography, please see p. 65 of June July 1953 General Motors Engineering Journal. This is the fourth contribution to this periodical b Mr. Richardson, head of the Administrative Engineer ing Department, Research Laboratories Division.

TEST	Engine A	Engine B
Test 1—Full Throttle as Installed	161 at 3600	149 at 3800
Test 6A—Maximum Power and Spark Timing Sensitivity with Non-Knocking Fuel	171 at 3800	160 at 4000
Test 7—Maximum Power and Detonation	173 at 4000	160 at 4000
Test 9—Heat Distribution	167 at 4000	152 at 3800
Test 20—Gross Engine Horsepower	199 at 4000	179 at 4000

Table I (Left)—The measured power output fo any engine is a function of the engine installatio and operating conditions. The newly adopte Test 20 gives the gross engine horsepower unde carefully specified conditions and will be used t establish advertised maximum horsepower for a GM passenger car engines.

valve. The production water pump, generator, distributor, coil, and fuel pump are used. The test is run at full throttle with the carburetor adjusted for maximum power and spark timing adjusted to *mbt*, minimum advance for best torque. The Society of Automotive Engineers correction factor is used so that power and torque are corrected to a dry air pressure of 29.92 in. Hg and a standard temperature of 60° F (Fig. 1).

The addition of Test 20 permits the Code to be used over an even wider range of operating conditions than before. Test 1—Full Throttle as Installed gives representative full throttle data over the speed range of the engine as installed in a car. At the other extreme is Test 20—Gross Engine Horsepower, which is used to measure the maximum power which can be obtained from the bare engine. Other standard tests in the Code cover other engine conditions which are needed in engine development.

A comparison of maximum horsepower, as obtained experimentally on two engines of different displacements and outputs, is tabulated in Table I to show how the use of different engine operating conditions as specified in the various individual tests can affect engine output. All tests were run in the same dynamometer room with the same instruments and operators. The only variables, therefore, were the test procedures as given in the Test Code.

In one typical case, for engine **A**, the engine power rating varied from 161 hp to 199 hp in six different tests. With another typical engine **B** the horsepower figure ranges from 149 to 179 in the same tests. These varying figures indicate the necessity of standard engine test procedures as given in the General Motors Automotive Engine Test Code. Comparisons of the power output of different engines are valueless unless the test procedures are the same. The use of the Code by all General Motors dynamometer laboratories assures that results obtained using the standard type tests can be directly compared by the various engineering groups.

In the future, all advertised horsepower values of General Motors passenger cars will be taken from Test 20—Gross Engine Horsepower. They will, therefore, represent values obtained under a standard published test procedure and will be directly comparable and reproducible.

Notes About Inventions and Inventors

By WARREN E. FINKEN
Patent Section
Dayton Office Staff

Written records—dated, signed, and witnessed—are important steps for inventor

THE importance of making proper invention records cannot be overemphasized. In fact, the act of making and retaining proper records to establish conception and reduction to practice of an invention and to establish diligence leading to an invention's actual or constructive reduction to practice is almost as important as the inventive act itself. This is particularly true where it becomes necessary for an inventor, in order to obtain a patent, to prove priority of invention over one or more additional inventors claiming the same invention. In such a situation, the inability of an inventor to prove or establish his conception, diligence, or reduction to practice of the invention may result in the refusal to grant him a patent otherwise rightfully his.

It is, therefore, important for inventors to understand generally what constitutes conception, reduction to practice, and diligence and what types of records are acceptable in proof thereof.

Definitions

Conception is a mental act. It is the formation in the mind of the inventor of a definite and permanent idea of the complete and operative invention as it is thereafter to be applied in practice.

Reduction to practice may be either constructive or actual. An actual reduction to practice is really the completed physical embodiment, in contrast to the completed mental embodiment, of the invention. In the case of a machine, an actual reduction to practice occurs when the machine is constructed, assembled, and successfully operated for its intended purpose. In the case of a process, actual reduction to practice takes place when the process is successfully performed. An article of manufacture is reduced to practice when it is completely manufactured and used successfully for its intended purpose. A composition of matter is reduced to practice when it is completely composed. A constructive reduction to practice is a complete and operative disclosure of the invention in the form of an application for patent properly filed in the United States Patent Office.

Diligence includes any act following the conception of an invention which tends to show that the inventor was actively reducing or attempting to reduce his invention to practice. Only reasonable diligence is required of an inventor, and the reasonableness of the acts constituting diligence varies in different cases, depending upon such factors as the nature of the invention and the time and money available to the inventor.

Acceptable Proofs

Conception can be established only by a disclosure of the invention to another person, or persons, capable of understanding it. This disclosure may be an oral disclosure. Preferably, however, it should be in the form of sketches and written descriptions sufficiently complete to enable one skilled in the art to reduce the invention to practice without the exercise of inventive skill. These sketches and written descriptions should be signed and dated by the inventor and by the person, or persons, to whom the disclosures were made.

Reduction to practice can never be proved by the unsupported testimony of the inventor. In other words, a reduction to practice of an invention must be witnessed by some person, or persons, other than the inventor, or inventors, and such witnesses should understand the invention and its operation or intended function. Oral testimony may be sufficient, but documentary evidence is more convincing. Accordingly, in the case of a machine or article of manufacture, the

machine or article of manufacture itself, or a full set of photographs thereof together with test data or other evidence of its successful testing or use, should be retained. All such material should be properly marked and dated and preferably signed by the witnesses so that it may be identified at a later date by the inventor and his witnesses.

In the case of a process, photographs of the apparatus used and documentary evidence of the steps performed, materials used, and results obtained should be carefully marked for identification and retained. The same is true for a composition of matter, although in this case it is well to record as many of its properties as possible.

Diligence, or the acts tending to show diligence on the part of the inventor, should also be corroborated by testimony of witnesses other than the inventor as in the case of conception or reduction to practice. The inventor should, therefore, to protect himself fully, keep a running record of the acts tending to indicate he was actively engaged in reducing his invention to practice, and these acts should be known to others.

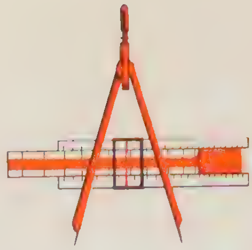
Summary

Under our law, the first conceiver of an invention, if he is reasonably diligent, from his conception date to his actual or constructive reduction to practice will be held in practically all cases to be the first inventor entitled to a patent. He will rarely lose this right to a patent if his invention records are complete, but he may lose this right to a later conceiver if his records are incomplete or unconvincing.

On this and on the following pages are listed some of the patents granted during the period from May 10 to July 31, 1954. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

Patents Granted

• **Howard M. Geyer*** and **Paul T. Keim,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Long-Stroke Fluid Servo, No. 2,678,247, issued May 11.* This patent pertains to a fluid-pressure-operated actuator. The principal feature of the actuator resides in the use of a glass liner which is surrounded by a protective metal sheath, the annular space therebetween being supplied with fluid under pressure so as to prevent bursting of the glass liner.



Mr. Keim is a project engineer with Allison. His current project is concerned with special tools and test equipment. He received the B.S. degree from University of Pittsburgh in 1942. Mr. Keim served as a first lieutenant in the Air Force as a fighter pilot and engineering officer from 1942 until 1946.

• **Howard C. Mead*** and **William T. Mears***, *Guide Lamp Division, Anderson, Indiana, for a Lamp Socket Mounting, No. 2,679,576, issued May 25.* This patent covers a vehicle tail lamp wherein the bulb and socket assembly is spring mounted in the rear of the housing to allow easy withdrawal without removing the lamp lens.

• **Paul E. Clingman***, *Inland Manufacturing Division, Dayton, Ohio, for a Sealing Strip, No. 2,679,915, issued June 1.* This patent relates to a sealing strip for connecting glass and metallic panels wherein the metallic panel includes a longitudinally extending groove.

• **William A. Fletcher***, *Delco-Remy Division, Anderson, Indiana, for a Sheet Metal Feeder, No. 2,680,018, issued June 1.* This patent relates to apparatus for intermittently feeding sheet metal into and out of a punch press. The feeding apparatus includes a pair of gripping jaws which are located at the entrance and exit of the machine so as to continuously maintain the sheet metal in alignment as it passes through the punch.

• **William A. Luther, Jr.,** *Moraine Products Division, Dayton, Ohio, for a Porous Metal Element, No. 2,679,683, issued June 1.* This patent relates to porous metal filter material and is particularly concerned with porous ferrous material of high porosity that has a complete covering of cuprous material all over the exposed surface thereof whereby the cost of the filter is reduced while the desirable qualities of the cuprous metal are made available in the filter.

Mr. Luther is a metallurgist in the Engineering Department at Moraine Products. He joined the Division after being graduated from Carnegie Institute of Technology in 1942 with the B.S. degree. At present, Mr. Luther is engaged in research and development to improve physical properties of powder metal parts. Prior to this, he worked on the development of metallic filter materials. One patent has been granted as a result of his work in the metallurgical field. Mr. Luther is a member of the A.S.M. and, in 1948, served as editor of the Dayton Engineers' Club monthly bulletin.

*Biographies of inventors marked with an asterisk in this section have been published in previous issues of the GENERAL MOTORS ENGINEERING JOURNAL.

• **David F. Moyer,** *Delco Products Division, Dayton, Ohio, for a Thermoprotective Switch, No. 2,680,172, issued June 1.* This patent relates to an electric motor overload protecting device to cover a wide range of motor current ratings by changing the mechanical relationship between the actuating components of the switch.

Mr. Moyer is a project engineer in the Engineering Department at Delco Products. He began his career with General Motors as a research engineer in the Department in 1951, and was promoted to his current duties in 1954 as project engineer—controls. As such, he is responsible for developments on electric motor controllers, motor protective devices, and voltage regulators. Mr. Moyer was granted the B.S. degree in electrical engineering by Massachusetts Institute of Technology in 1946. Before coming to GM, he was a consulting engineer in electrical and acoustical design for three years, and a field engineer with the Ultrasonic Corporation for two years. He is an associate member of the A.I.E.E.

• **Ralph K. Shewmon,** *Delco Products Division, Dayton, Ohio, for an Electric Switch, No. 2,680,167, issued June 1.* This patent relates to an electric control switch having an improved snap acting actuating structure comprising a ball and cam.

Mr. Shewmon is section engineer—fractional motors in Delco Products' Engineering Department. In this capacity he coordinates customer developments a

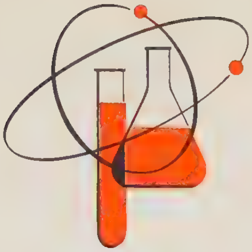
hey affect fractional-horsepower motor design. His GM career began in 1930 at GM Radio Division where he was employed as a General Motors Institute cooperative student. He completed the four-year program in industrial engineering at G.M.I. in 1934. In 1932 he was transferred to Delco Products and was later promoted through the positions of draftsman, junior, and senior design engineer to his present post. Mr. Shewmon is a member of the Dayton Engineers Club. This is the latest in a series of several patents granted as a result of his work in fractional-horsepower motor design.

• **Robert C. Treseder***, *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Propeller Control, No. 2,679,908, issued June 1.* This patent relates to apparatus for synchronizing the speeds of a plurality of engine-propeller combinations with a reference speed source including means for sensing speed errors and means for adjusting the load on the erring engine-propeller combination.

• **John Dickson***, *Detroit Diesel Engine Division, Detroit, Michigan, for an Engine Lubrication System, No. 2,680,494, issued June 8.* This patent relates to an engine lubricating system which purifies oil in a centrifuge located in the camshaft before delivering the oil to the main engine bearings.

• **Gordon W. Harry**, *AC Spark Plug Division, Flint, Michigan, for a Throttle Dashpot, No. 2,680,610, issued June 8.* This patent relates to a device which may be used as a pump or dashpot and consists of a casing having a diaphragm mounted therein with control means that permit substantially free flow of fluid through the diaphragm when it moves in one direction and restricted flow therethrough when moving in the opposite direction.

Mr. Harry serves as experimental engineer at AC Spark Plug. He was originally employed by the Division as a designer in 1925. Since then he has advanced through the positions of junior engineer, assistant experimental engineer, assistant section engineer, and development engineer to his present position. His current major projects deal with fuel pumps and vacuum pumps. His work in these areas has resulted in 10 patents. Mr. Harry received the B.S. degree in mechanical engineering from



University of Michigan in 1923. He is a member of the Society of Automotive Engineers.

• **Clarence H. Jorgensen***, *Rochester Products Division, Rochester, New York, for a Variable Speed Windshield Wiper, No. 2,680,262, issued June 8.* This patent relates to vehicle windshield-wiping apparatus including a fluid motor for each wiper blade. The speed of the fluid motors is controlled by a variable speed transmission that actuates a flow controlling valve.

• **Henning W. Rundquist and Gilbert Burrell***, *Oldsmobile Division, Lansing, Michigan, for a Fuel Strainer with Magnet, No. 2,680,519, issued June 8.* This patent relates to a fuel strainer having a magnet located in the path of the incoming fuel to separate magnetic particles before the fuel passes through an edge-type strainer.

Mr. Rundquist's position as senior project engineer in Oldsmobile's Product Engineering Department deals primarily with developmental work on carburetor design. He has been with that Division since 1929 when he was first employed as a clerk in Product Engineering. Various promotions through the positions of cold-room engineer, transmission engineer, gun-development test engineer, senior test engineer, and project engineer led to his present position. Mr. Rundquist received the B.S. degree from Michigan State College in 1929. He is a member of the Society of Automotive Engineers. This is the second patent granted as a result of his work, the first resulting from previous projects on gun development.

• **Lucian B. Smith**, *AC Spark Plug Division, Flint, Michigan, for a Coil Turn Tester, No. 2,680,835, issued June 8.* This patent relates to a test fixture for quickly and accurately measuring the number of turns in a multi-turn coil by comparison with a standard, and which can be preset for different coils.

Mr. Smith is chief test engineer in the Automotive Test Laboratory at AC Spark Plug. Originally employed as a test laboratory assistant in 1923, he was promoted to assistant head of the Test Laboratory in 1927, to test engineer in 1930, to test engineer on military products in 1942, and to his present position in 1947. Ohio State University granted Mr. Smith the B.E.E. degree in 1923 and he was elected to the honorary electrical engineering fraternity, Eta Kappa Nu, and to the honorary mathematics fraternity, Pi Mu Epsilon. He is a member of the Society of Automotive Engineers and the American Institute of Electrical Engineers. This is the tenth patent granted as a result of his developments in the field of automotive components.

• **Elmer Olson***, *Rochester Products Division, Rochester, New York, for an Automatic Choke Device for Carburetors, No. 2,681,215, issued June 15.* This patent relates to a method of initially setting the thermostat of a thermostatic choke device for any given temperature, in which operation of the thermostat is compared with that of a master thermostat.

• **Robert C. Treseder***, *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Fluid Control System for Variable Pitch Propellers, No. 2,681,116, issued June 15.* This patent relates to speed governing apparatus for variable pitch propellers including a solenoid-actuated pulsing valve and means for varying the time duration of the pulses in accordance with deviations in propeller speed from a reference speed source.

• **Edward L. Barcus***, *Guide Lamp Division, Anderson, Indiana, for a Directional Signaling Device, No. 2,681,956, issued June 22.* This patent relates to improvements in self-cancelling direction signal switch operating mechanisms.

• **William E. Brill***, *Cleveland Diesel Engine Division, Cleveland, Ohio, for a Slipper-Type Bearing Structure, No. 2,681,838, issued June 22.* This patent relates to a positive locking arrangement for securing bearing shells in the crankshaft end of slipper-type connecting rods.

• **Grove S. Dow, Jr. and Howard I. Slone**, *Guide Lamp Division, Anderson, Indiana, for an Optical Traffic Signal Viewer, No. 2,681,-589, issued June 22.* This patent relates to a traffic signal viewer having a generally wedge-shaped lens element with a con-

cave viewing surface, a conical top surface, and a plain light gathering surface together with mounting means to provide universal movement.

Mr. Dow is no longer with the Division.

Mr. Slone is accessory engineer in the Engineering Department at Guide Lamp. He was originally employed in that Department in October 1938 in a garage service position. In 1940 he was made a lens optic designer, in 1941 specifications engineer, and in 1945 he was promoted to his current position. Mr. Slone was graduated from Purdue University in 1938 with the B.S. degree in electrical engineering. This is the second patent granted as a result of his work in the field of automotive electrical components. He is a member of the Fuse Subcommittee of the GM Electrical Fittings Committee.

• **Elbert L. Johnson***, *Packard Electric Division, Warren, Ohio, for a Connector, No. 2,682,038, issued June 22.* This patent relates to a line connector in which a spade terminal connected to one conductor is clamped between a resilient tongue and edges forming part of the terminal connected to a second conductor. The tongue has a projection that engages an opening in the first terminal to hold the terminals together, the terminals being covered by an insulating sleeve.

• **William J. Purchas, Jr.*, Robert C. Moser, and Eugene B. Etchells***, *Diesel Equipment Division, Grand Rapids, Michigan, and Chevrolet Motor Division, Detroit, Michigan, respectively, for a Hydraulic Lash Adjuster, No. 2,681,644, issued June 22.* This patent relates to the porting arrangement of the plunger and cylinder of a hydraulic valve lifter supplied from the engine oil pressure system to prevent sticking from accumulations of varnish-like deposits on the sliding surfaces.

Mr. Moser is no longer with the Division.

• **Paul L. Schneider***, *Delco-Remy Division, Anderson, Indiana, for an Air Velocity Responsive Snap Action Switch, No. 2,681,957, issued June 22.* This patent relates to a system for controlling the horns of a vehicle so that, after the vehicle exceeds a predetermined speed, an automatic switch responsive to the air speed of the vehicle will close a circuit so that more than one horn will be energized, thereby increasing the intensity of the warning tone.

• **Harold V. Elliott***, *Delco-Remy Division, Anderson, Indiana, for a Terminal for Electrical Apparatus, No. 2,682,570, issued June 29.* This patent relates to a terminal construction for ignition timers wherein the terminal is supported in an aperture of a metallic housing by a pair of telescopically arranged bushings of nonconducting material.

• **John O. Almen***, *Research Laboratories Division, Detroit, Michigan, for a Pre-stressed Brake Disc, No. 2,682,936, issued July 6.* This patent relates to a railway-type brake disc which is pre-stressed so that the braking surfaces are in tension and the central region is in compression to retard the growth of cracks in the disc.

• **Edward L. Barcus***, *Guide Lamp Division, Anderson, Indiana, for a Switch, No. 2,683,193, issued July 6.* This patent relates to an electric switch for use in turn-signal devices including a detent mechanism providing a snap action to return the switch contacts from the left or right turn position to the neutral position.

• **Charles G. Crowe**, *Hyatt Bearings Division, Harrison, New Jersey, for a Closure Apparatus, No. 2,682,968, issued July 6.* This patent relates to a gasoline filler tube closure member. The closure member carries a spring-pressed cup which seals the end of the filler tube and a separate trip plate is provided for releasing the closure latch.

Mr. Crowe serves as a designer in the Engineering Department of Hyatt Bearings. His General Motors career began in the Styling Section in September 1945. In November 1951 he transferred to his present position in which he is currently engaged in developmental work on railroad journal boxes. During his work at the GM Styling Section, his duties included the development of automobile door locks and layout work for many components of both standard and special GM car models. Mr. Crowe was awarded the Certificate in Machine Design from Pratt Institute in 1939. This is the first patent resulting from his design work on automobile bodies.

• **Rea I. Hahn***, *Rochester Products Division, Rochester, New York, for a Method and Apparatus for Metal Coating Tubing, No. 2,683,099, issued July 6.* This patent relates to a method and apparatus for coating steel tubing with copper or other nonferrous metal in which the coating material is heated in a crucible by high frequency a-c current which causes the metal to rise at the center of the crucible. The tube to be coated is drawn through this raised portion of the coating metal.

• **Michael J. Kreutzer**, *Frigidaire Division, Dayton, Ohio, for a Forming Tool for Reducing Stock, No. 2,682,848, issued July 6.* This patent relates to a forming tool which engages tubular stock to be reduced through considerably less than 50 per cent of its circumference. A pilot element carried by the tool limits the internal diameter of the stock and forms an internal shoulder on the stock.

Mr. Kreutzer is foreman of the Experimental Tool Department at Frigidaire. His General Motors employment dates back to 1924 when he was with Delco Light's Service Manufacturing Department. He transferred in 1925 to Frigidaire's tool room in Plant No. 2. Regular promotions through the various tool departments at that Division led to his present position where he has engaged in developmental work on tools to improve production and on special equipment for the production of babbitt bearings. Two patents have resulted from his work. Mr. Kreutzer studied tool making through the International Correspondence School.

• **Thomas O. Mathues**, *Inland Manufacturing Division, Dayton, Ohio, for a Transfer Mold for Use in the Manufacture of Sponge Rubber-like Articles, No. 2,682,685, issued July 6.* This patent relates to a transfer mold for use in the molding of rubber-like articles from latex foam wherein the foam may be transferred from a central cavity into a molding cavity. This is accomplished by utilizing an open mold cavity whereby the latex foam is maintained at substantially atmospheric pressure through the transferring operation.

Mr. Mathues has served as director of Laboratories at Inland since 1952. He joined the Division in 1940 as an engineering student and was promoted to junior estimator in 1944, to junior test engineer in 1946, to project engineer—latex products in 1948, to supervisor of the Physical Test Laboratory in 195

and to his present position in 1952. His previous work with solid rubber, foam rubber, and electrical accessories has resulted in three granted patents. Mr. Mathues was granted the B.M.E. degree from General Motors Institute in 1947. His technical affiliations include chairmanship of the Dayton Section of the S.A.E. and membership in the American Society for Testing Materials. His committee work includes work on the S.A.E. Committee for the Laboratory Evaluation of Brake Linings.

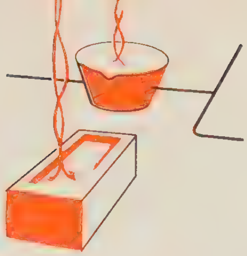
• **George W. Onksen, Jr.***, *Guide Lamp Division, Anderson, Indiana, for a Signal Reflector, No. 2,682,807, issued July 6.* This patent relates to a reflector element having substantially cube corner reflecting surfaces, the surfaces of each cube being disposed with respect to each other at an angle of 90° plus or minus a specified correction angle in order to provide improved light distribution.

• **Stanley R. Prance***, **and Harold J. Reindl***, *Inland Manufacturing Division, Dayton, Ohio, for a Method of Finishing Ice Trays, No. 2,683,113, issued July 6.* This patent relates to a method for processing aluminum ice trays and the like wherein the trays are brightened, anodized, dyed, and waxed in continuous operation.

• **Harold J. Reindl*** **and Stanley R. Prance,*** *Inland Manufacturing Division, Dayton, Ohio, for a Method of Electroplating, No. 2,683,112, issued July 6.* This patent relates to a method for plating steering wheels and the like wherein metal cored nonmetallic materials may be plated through the use of a conducting covering such as graphite or metal particles thereover, and wherein spaced conducting pins are provided which extend from the core to maintain fixed areas to be plated.

• **Harold W. Schultz,** *Moraine Products Division, Dayton, Ohio, for an Apparatus for Bonding Brake Linings to Brake Shoes, No. 2,682,908, issued July 6.* This patent relates to apparatus for bonding brake linings to brake shoes wherein a plurality of circumferentially located pressure applying means individually distribute the pressure evenly over the surface of the lining during the bonding operation.

Mr. Schultz has been section engineer at Moraine Products since 1952 and a member of this Division's Engineering Department since 1937. In the past, he



has worked on metallurgical bonding of aluminum to steel, plating aluminum with lead-tin depositions, and the development of cements for bonding friction materials to metallic members. Currently, he is engaged in the development and production engineering of friction materials for automatic transmissions and related devices. Mr. Schultz's work on aluminum cladding to steel, plating, friction materials, and adhesives has resulted in 11 patents. He is a member of the Society of Automotive Engineers, and serves on the Thermosetting Adhesives Committee of the American Society for Testing Materials.

• **Homer T. Wright,** *Frigidaire Division, Dayton, Ohio, for a Forming Tool for Reducing Stock, No. 2,682,849, issued July 6.* This patent relates to a forming tool having a stock engaging member and a guide member, both of which are removably supported in a holder mountable in a conventional drill press. The stock engaging member may be replaced without replacing the guide member.

Mr. Wright is supervisor of tool engineering at Frigidaire's Plant No. 2. His initial employment with that Division was in 1939 as a co-op student in industrial engineering at General Motors Institute. Following his graduation from G.M.I. in 1943, he was made a junior tool engineer, serving in this capacity until 1950 when he was made assistant tool engineer. In 1952 he was placed in charge of the Tool Engineering Group at Plant No. 2, his present position. This is the first patent resulting from Mr. Wright's work in the field of tool engineering.

• **Charles R. Gillette and William P. Burroughs,** *New Departure Division, Bristol, Connecticut, for a Tumbling Process, No. 2,683,343, issued July 13.* This patent relates to a tumbling process wherein completed miniature ball bearings are slowly tumbled in jumbled relation in a cleaning solution which removes the small amount of dirt, smut, and/or oxides that may have adhered to the bearing during the processing and assembly of its parts. The tumbling process also embodies a very finely comminuted abrasive in suspension which produces a final lapping operation on the bearing surfaces to reduce their starting torque.

Mr. Gillette serves as chief chemist in the Product Engineering Department at New Departure. He began his career with that Division as a routine chemist in 1925. In October 1942 he was appointed assistant chief chemist and in June 1947 he attained his present position. He has undertaken developmental work in such diversified areas as metal cleaning, rust prevention, packaging, bearing greases, and lubrication and process supplies. Mr. Gillette is a member of the American Chemical Society, American Society of Lubrication Engineers, and serves on committees for the American Society of Mechanical Engineers, American Society for Testing Materials, and Coordinating Research Council.

Mr. Burroughs is experimental chemist in the Chemical Section of the Product Engineering Department at New Departure. He was initially employed as a routine chemist in 1935, and regular promotions within the Department led to the position he now holds. As experimental chemist, his major project involves solving problems of rust prevention and metal cleaning. Mr. Burroughs is a member of the Middletown Scientific Association of Wesleyan University, Middletown, Connecticut.

• **Harold V. Elliott***, *Delco-Remy Division, Anderson, Indiana, for a Lock Washer, No. 2,684,098, issued July 20.* This patent relates to a lock washer including means for preventing rotation thereof when a securing nut is assembled with a stud.

• **Roy P. Hipple,** *Packard Electric Division, Warren, Ohio, for an Apparatus for Forming Terminals and Attaching Same to Wires, Nos. 2,684,421 and 2,684,423, issued July 20.* These patents relate to machines for forming terminals from a metal strip and attaching these terminals to conductors. The machines include means for forming the terminals with ears, bending the ears to grip conductors, severing the terminals from the strip, and thereafter welding the terminals to the conductors.

Mr. Hipple is supervisor of Tool and Machine Tool Engineering in the Tool and Process Engineering Department at Packard Electric. He was originally employed in that Department in September

1936 and regular advancements have led to his current position. In this capacity, he is responsible for the development of new processes for manufacturing various components of cable assemblies and fractional-horsepower motors. Mr. Hipple is a 1938 graduate of General Motors Institute and is a member of the American Society of Tool Engineers. Two patents have resulted from his work with electrical wiring.

• **James W. Jacobs***, *Frigidaire Division, Dayton, Ohio, for an Indicator for Refrigeration Apparatus, No. 2,683,970, issued July 20.* This patent relates to a vertical home freezer cabinet where an electric lamp is connected in the motor circuit of the refrigerating system, the lamp being continuously energized during operation of the system. The lamp is visible through the cabinet door and indicates that a proper freezing temperature is being maintained in the cabinet.

• **Stanley R. Prance*** and **Harry O. Waag***, *Inland Manufacturing Division, Dayton, Ohio, for a Plastic Coating Composition and Plastic Article Coated Therewith, No. 2,684,310, issued July 20.* This patent relates to a transparent coating for use on the surface of articles formed from methyl methacrylate resin. The coating enhances the appearance thereof and consists of nitrocellulose having a 60 to 80 viscosity, and a solvent consisting of acetone and amyl acetate.

• **Herbert C. Schryver**, *Packard Electric Division, Warren, Ohio, for a Machine for Assembling Nipples on Cables, No. 2,683,924, issued July 20.* This patent relates to a machine for assembling rubber nipples over the ends of conductor cables. The machine includes means for positioning a nipple on a sleeve, moving a conductor into the sleeve, and withdrawing the sleeve—leaving the nipple positioned on the conductor.

Mr. Schryver is senior engineer in the Tool and Process Engineering Department at Packard Electric. He began his General Motors' employment as an engineer in this same Department in 1940. Ten years later, he was promoted to supervisory duties as senior engineer. His previous work has included the development of processes for automatic stator winding which has led to one granted patent. The patent listed above is the second to result from his work. Purdue University awarded Mr. Schryver the B.S. degree in mechanical engineering in 1940.

• **Robert O. Scofield**, *Packard Electric Division, Warren, Ohio, for an Extruder, No. 2,683,895, issued July 20.* This patent relates to apparatus for extruding plastic material around a wire. The apparatus includes a feed screw for forcing the material through an extruder head, two rotating kneading devices between the feed screw and the extruder head, and means for adjusting the speed of the kneading devices relative to the feed screw and to each other.

Mr. Scofield serves as supervisor of design projects in the Tool and Process Engineering Department at Packard Electric. His career with that Division dates back to 1925 when he was assistant foreman of the Rubber Department. In March 1936 he transferred to his present Department as draftsman. He was made group head of Special Projects in 1938, and he advanced to his present position in 1940. Mr. Scofield studied mechanical engineering at the International Correspondence School. Among his major projects have been the development of fixture assemblies for both motors and wiring harness, nylon magnet wire, and automatic stator winding machines. This is the second patent granted as a result of his work in these fields.

• **Forest L. Zion***, *Delco-Remy Division, Anderson, Indiana, for a Method of Making Clamping Rings, No. 2,683,922, issued July 20.* This patent relates to a method for making annular rings from coiled material wherein at least two turns are severed from the coil, which segment is then coined to provide the desired cross section.

• **John Mynar, Jr.**, *Chevrolet Motor Division, Detroit, Michigan, for an Automatic Nut Loading Machine, No. 2,685,018, issued July 27.* This patent relates to an apparatus which automatically conveys nuts or similar fastening devices from a hopper to a sheet metal panel and properly positions the nuts on the panel preparatory to being projection welded thereto.

Mr. Mynar serves as senior engineer in the Die Engineering Department of Chevrolet Motor. He began in the Pressed Metal Division of Chevrolet Motor in 1940 and was enrolled as a cooperative engineering student at General Motors Institute. He was awarded the Bachelor of Industrial Engineering degree by G.M.I. in 1950 and shortly afterward was made process engineer in his present Department. He was advanced to senior engineer in 1953. This is the first patent resulting from Mr. Mynar's work with production equipment.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

• **Earl W. Pierce and Michael Skunda**, *AC Spark Plug Division, Flint, Michigan, for a Spark Plug Tester, No. 2,685,059, issued July 27.* This patent relates to a spark plug testing machine wherein an operating ram, acting through the spark plug, actuates a pump to force oil under pressure around the electrode to insulate the spark gap so that the test voltage may be applied across the spark plug insulator.

• **Earl W. Pierce and Raymond C. Wampole**, *AC Spark Plug Division, Flint, Michigan, and Milwaukee, Wisconsin, respectively, for a Spark Plug Tester, No. 2,685,060, issued July 27.* This patent relates to an improved miniature spark plug testing machine having an operating ram which engages the spark plug to move a pump element and force oil under pressure around the electrodes to insulate the spark gap and to maintain the oil level constant so that a minimum spark plug movement is required to actuate the pump.

Mr. Pierce is senior project engineer in AC Spark Plug's Engineering Department. He was originally employed in the Works Engineering Department shortly after receiving the B.S. degree in mechanical engineering from University of Michigan in 1939. Mr. Pierce has participated in several phases of engineering at AC, including manufacture of machine guns and spark plug designing for automotive, aircraft, and Diesel engine use. In addition, he has acted as a technical representative for AC at various manufacturers and government agencies. He is currently engaged in igniter plug development. Mr. Pierce is a member of the S.A.E. This is the first patent resulting from his work.

Mr. Skunda serves as senior designer in AC Spark Plug's Engineering Department. His first position with that Division was as senior gage designer in the Gage Design Department in 1939. Regular promotions led to his current position in

the Spark Plug Engineering Department, where he is responsible for the development of spark-plug seals. Previous assignments have included the problem of controlling ceramic shrinkages. Mr. Skunda is past chairman of the Saginaw Valley Chapter of the American Society of Tool Engineers. This is the initial patent resulting from his developmental work on spark plugs.

Mr. Wampole is tool engineer at the Milwaukee plant of AC Spark Plug. His initial employment with General Motors began in 1938 at Chevrolet Motor Division in Muncie, Indiana, where he was a co-op student of General Motors Institute. In 1944, two years after graduating from G.M.I., he transferred to AC Spark Plug Division, Flint, Michigan, as a tool designer. In July 1948 he was promoted to senior tool designer and four months later he transferred in this same capacity to the Milwaukee plant. He is currently engaged in engineering development on assembly of navigational aids. Mr. Wampole is a member of the American Society of Tool Engineers.

• **Harold J. Schoelles***, *Harrison Radiator Division, Lockport, New York, for an Automatic Heating System, No. 2,684,620, issued July 27.* This patent relates to a car heating unit which is adapted to be secured to the fire wall including means for controlling and distributing the air flow therethrough for heating and windshield defrosting purposes.

• **Fred J. Webbere**, *Research Laboratories Division, Detroit, Michigan, for an Intermediate Alloy and Process for Forming Wear-Resistant Cast Iron, No. 2,684,900, issued July 27.* This patent relates to a method of forming highly wear-resistant cast iron by a ladle addition of an intermediate alloy containing small amounts of titanium and phosphorus.

Mr. Webbere serves as supervisor of alloy-development melting in the Metallurgy Department of the Research Laboratories. He was appointed to his present post in April 1954 after advancing through the positions of research metallurgist and senior engineer. He began in this Department in 1941 as junior engineer following his graduation from University of Wisconsin with the degree of Bachelor of Science. He has been elected to Tau Beta Pi and he is a member of the American Society for Metals and the American Foundrymen's Society. This is the second patent resulting from his work.

Recent Speaking Engagements Filled by GM Engineers

Among American engineers there exists a tradition of informing each other about new developments in their fields and how they solved some of their unusual problems. A certain stimulation prevails in "talking things over" and in learning from others. Engineering, as a whole, benefits from such activity. Thus, a great many engineers derive considerable satisfaction in talking before groups who are interested in technical developments—groups like national and local engineering societies, student classes, college forums, and some non-technical civic organizations.

General Motors engineers share this interest in discussing engineering developments with others, and throughout the year their speaking engagements cover a wide variety of subjects representative of the many kinds of scientific and technical work carried on in the organization. Listed below are the appearances made during the summer months by engineers from various Divisions and Staffs before groups outside of GM.

Engineering educators are reminded that requests may be directed to the Educational Relations Section for assistance in obtaining the services of General Motors engineers to speak before engineering classes or other student groups.

On September 15 **Howard L. Roat**, master mechanic at AC Spark Plug Division, outlined "Trends in Industrial Engineering" before the Mott Foundation adult education teachers meeting in Flint, Michigan.

R. M. Schaefer, manager of the Transmission Engineering Department at Allison Division, addressed the National West Coast Meeting of the Society of Automotive Engineers held in Los Angeles, California, on August 16-18. The title of his talk was "Transmission Development for Trucks and Buses."

Tom Gillespie, chief test pilot at the Kansas City plant of B.O.P. Assembly Division, described "The First Test Flight of the F-84F" to members of the Reserve Air Force Unit in Kansas City, Missouri, on August 19.

L. C. Goad, executive vice president of General Motors, delivered the commencement address at the 27th annual commencement of General Motors Institute on August 6.

On September 15 **Shirrell C. Richey**, assistant staff engineer in the Passenger Car Body Group of Chevrolet Motor Division, appeared before the Penninsula Subsection of the Virginia Section, American Society of Mechanical Engineers. The topic of his talk was "The Corvette Plastic Body."

Zora Arkus-Duntov, assistant staff engineer in the Research and Development Section of Chevrolet Motor, outlined "The Essentials of Road Racing" before the September 29 meeting of Division XX on shot peening of the S.A.E. Iron and Steel Technical Committee held at Hot Springs, Virginia.

On September 22 **Eric R. Brater**, assistant chief engineer in the Engineering Department of Cleveland Diesel Engine Division, spoke to the Engineers Club of Corpus Christi, Texas, on the topic "Development of a Large, Vertical, Radial, Gas Engine."

W. King Simpson, technical director—fuels and lubricants in the Engineering Department of Electro-Motive Division discussed "The Economics of Using Low Grade Diesel Fuel" at the August 10 meeting of the Southeastern Railway Diesel Club in Jacksonville, Florida.

In Kansas City, Missouri, on September 2, **Gil F. Roddewig**, experimental engineer in the Engineering Department of GMC Truck and Coach Division, discussed "Truck Noise" before a group of truck operators and councilmen of Kansas City.

J. Ralph Holmes, chief engineer at Harrison Radiator Division, described "Automotive Air Conditioner Component Location and Coordination" before the Motor Vehicle Air Conditioning Forum of the Texas Section of the Society of Automotive Engineers. The forum was held in Dallas, Texas, on September 17.

On September 23 **L. D. Cobb**, manager of research and development in the Product Engineering Department of New Departure Division, appeared before the

reserve officers of the Navy Research Section at Hammond Laboratory, Yale University. The title of his talk was "Research on Gas Turbine and Jet Engine Bearings."

J. P. Charles, assistant chief engineer in the Engineering Department of Pontiac Motor Division, spoke at the Conference on Vehicle Combustion Products of the Southern California Air Pollution Foundation held on August 20 in Pasadena, California. His topic was a "Report on Coordinating Research Council Project on Exhaust Gas Composition."

"Test and Service Experience with Shot Peened Gears" was the title of a talk given by **Robert Schilling**, head of the Engineering Mechanics Department of Research Laboratories Division, before the Navy Gear Industry Committee held in Washington, D. C., on August 25.

At the Institute for Mathematics Teachers held at the University of Virginia on August 9, **Leonard Lustick**, research engineer in the Gas Turbines Department of the Research Laboratories Division, discussed "The Application of Mathematics in Gas Turbine Research."

Paul L. Cramer, assistant department head, and **Charles R. Begeman**, senior research engineer, both of the Fuels and Lubricants Department of Research Laboratories Division, presented the paper "Thermal Diffusion Separations of Certain Organic Liquid Mixtures" before the American Chemical Society at its meeting in New York City, September 11-17.

At the Fifth International Symposium on Combustion held at the University of Pittsburgh from August 30 to September 4, **William G. Agnew**, senior research engineer in the Fuels and Lubricants Department of Research Laboratories Division, in conjunction with John T. Agnew, professor of mechanical engineering, and Kenneth Wark, research associate—both of Purdue University—discussed "Infrared Emission from Cool Flames: (A) Stabilized Cool Flames; (B) Engine Cool Flame Reaction; (C) Gas Temperatures Deduced from Infrared Emission."

John Campbell, technical director of Research Laboratories Division, was the banquet speaker at the S.A.E. National West Coast Meeting held in Los Angeles, California, from August 16-18. The topic of his talk was "What Are We Doing About Combustion."

A Typical Problem in Engineering:

Find the Wheel Loads of a Railway Truck of Novel Design

By IVAN H. SPOOR
Electro-Motive Division

The design of Diesel locomotives presents not only engine problems but also car-structure problems and locomotive-truck problems. Locomotive trucks operate under very severe conditions exposing axles, wheels, and truck structures to high loads and stresses. It is important, therefore, that the wheels carry loads as nearly equal as possible. From considerations of safety a train can be wrecked by a lightly loaded wheel which may jump the track. Trucks are, therefore, open to possibilities of redesign.

Wheel loading affects wear and safety of train operation

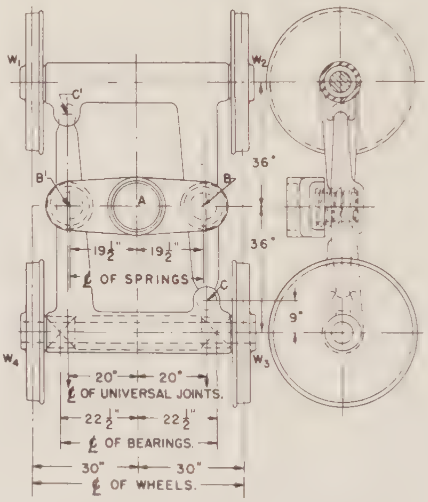


Fig. 1—Approximation sketch of a railway truck of novel design. The flexibility of the truck is provided for by the use of universal joints, located at **C** and **C′**, which permit the truck structure to pivot.

NOVEL designs often are studied by the engineer in his search for an improved product. Some of these designs may be developed successfully, while others may prove unsuitable in their early stages and, therefore, be rejected completely. The product engineer can expect many occasions where he must explore a number of the so-called "unique" designs before an ultimate design is reached and working drawings prepared.

Shown in Fig. 1 is a problem arising from one of these unique designs. The actual design that was considered (of which the sketch is only an approximation) received considerable attention until an inherent fault was discovered. In spite of the apparent symmetrical design, the wheel loads are not equal. The characteristics of wheel loading must be determined, therefore, in order to pursue this design further.

Problem

The truck supports a load of 100,000 lb at point **A** through the bolster and spring supports. Points **B** and **B′** denote the location of the spring supports. The flexibility of the proposed truck is provided by the use of universal joints, at the locations indicated by **C** and **C′**, to permit the truck structure to pivot.

This problem has two parts which are of importance to the engineer:

(a) Calculate the load at each wheel, $\mathbf{W_1}$, $\mathbf{W_2}$, $\mathbf{W_3}$, and $\mathbf{W_4}$.

(b) What are the general corrections which can be made without changing the basic design to result in the condition of equal wheel loading for the proposed truck?

The solution and discussion of the problem will be given in the January-February 1955 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Solution to the Previous Problem:

Determine the Length of the Governor Valve in the Hydra-Matic Automatic Transmission

By GEORGE R. SMITH

General Motors
Engineering Staff

Applying the centrifugal force of a spinning mass principle

The function of the governor in the Hydra-Matic automatic transmission is to meter oil pressure—varying with car speed—to the shift control valve. Two governor valves are necessary in the governor assembly to insure that the transmission will automatically shift gear ratios under all conditions of light throttle and full throttle operation. This is the solution to the problem for determining the length of the G_2 governor valve presented in the September-October issue of the GENERAL MOTORS ENGINEERING JOURNAL. The mathematical solution shows that the length of the G_2 valve must be 1.7938 in. to assure that governor pressure will continue to rise past the last shift point which is at 75 mph.

THE first step in the solution to the problem of determining the section of length L of the G_2 governor valve (shown detailed in Fig. 1) necessary to produce the G_2 curve shown in Fig. 2 is to determine the center of gravity and weight of all the known portions of the G_2 valve body cylindrical sections. When this step is completed, a summation of the known individual centrifugal forces can then be computed. The difference between the summation of the individual centrifugal forces and the inward hydraulic force will equal the force that must be produced by the G_2 valve end section.

The hydraulic responsive area of the G_2 valve which will regulate an inward hydraulic force to oppose its outward centrifugal force will be equal to the area of the inner end of the valve minus the area of the end section of the valve. The hydraulic responsive area, therefore, is equal to:

$$\pi/4\ (0.69875)^2 - \pi/4\ (0.39075)^2 = 0.262 \text{ sq in.}$$

It was previously stated that the length of the G_2 governor valve could be determined for any car speed because both the G_2 curve and the centrifugal force varied as the square of the car speed. This solution is based on a car speed corresponding to a 3,200 rpm governor speed. At this car speed the regulated G_2 pressure, from Fig. 2, is equal to 65 lb per sq in. With this information it is now possible to determine the inward hydraulic force which will be opposed by the centrifugal force of the G_2 valve. The inward hydraulic force will be equal to the G_2 valve pressure at the arbitrary speed of 3,200 rpm times the hydraulic responsive area, or:

$$\text{inward hydraulic force} = 65 \text{ lb per sq in.} \times 0.262 \text{ sq in.}$$

$$\text{inward hydraulic force} = 17 \text{ lb.}$$

The centrifugal force F of the G_2 valve can be calculated by means of the fundamental centrifugal equation which, when simplified to include the units used for this specific problem, will be equal to:

$$F = 0.284\ WR\ (N/100)^2$$

where

F = centrifugal force of G_2 valve body (lb)

W = weight of G_2 valve body (lb)

R = radius from the center of gravity of the G_2 valve to the centerline of rotation of the governor (in.)

N = rpm of G_2 valve.

The centrifugal force F of the entire G_2 valve body is equal to 17 lb, following from the statement that the centrifugal force of the valve will be opposed by the

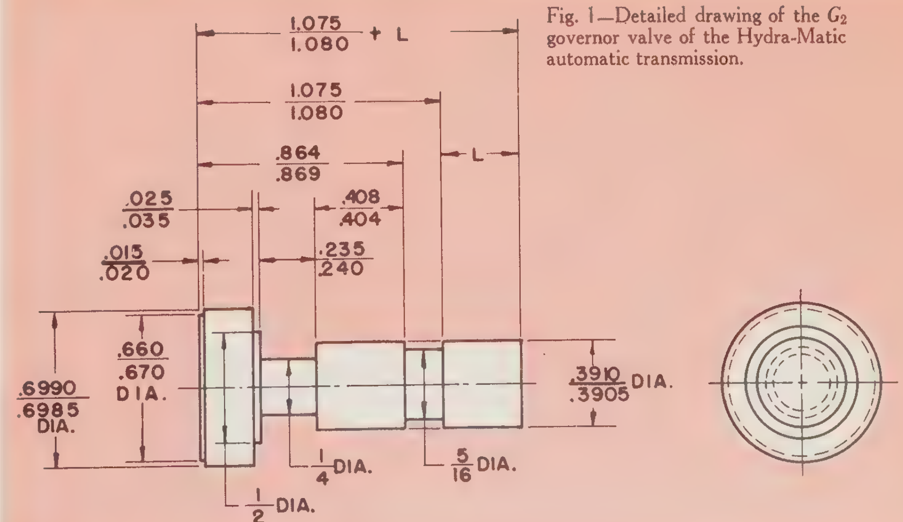


Fig. 1—Detailed drawing of the G_2 governor valve of the Hydra-Matic automatic transmission.

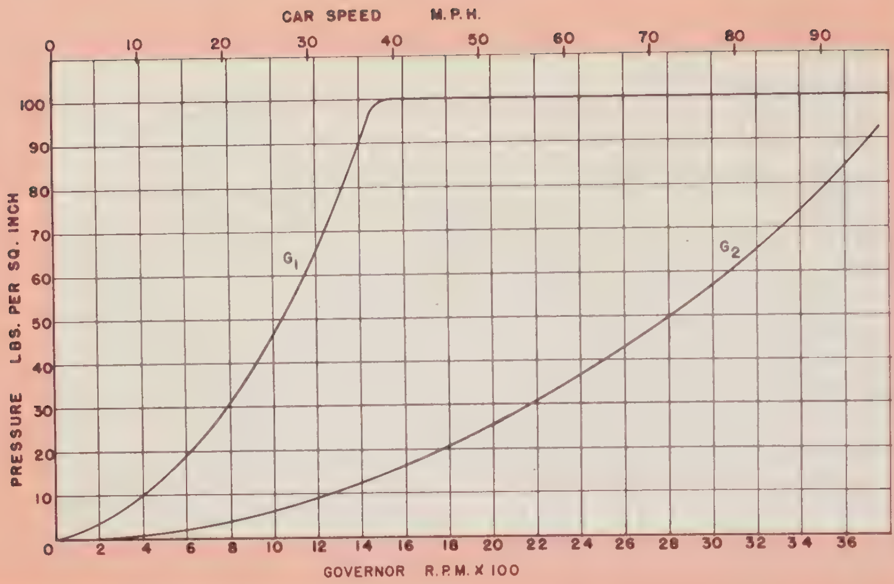


Fig. 2—Regulated pressure rise of governor valve G_2 with increase in car speed. It is necessary that the length of the G_2 governor valve be accurate so that the governor pressure will continue to rise past the last shift point, which is at 75 mph, and that the pressure rise, per mile per hour, be relatively high.

inward hydraulic force. The exact values for W and R are unknown and are dependent upon the section of length L of the valve. The product WR for the entire valve body is equal to the summation of the product of the weight of each valve cylindrical section and the radius of its center of gravity from the centerline of rotation of the governor. If known values are substituted into the centrifugal force equation, the following expression will result which will represent the total WR value for the G_2 valve:

$$F = 0.284\ WR\ (N/100)^2$$

$$17 = 0.284\ WR\ (3200/100)^2$$

$$WR = 17/290.82 = 0.0585 \text{ lb-in.}$$

Fig. 3 shows a sketch of the G_2 valve body on which the center of gravity of each cylindrical section of the valve is designated and also dimensions pertinent to the solution of the problem. The difference between the total WR value of 0.0586 lb-in. for the entire valve body and the sum of the WR values for each cylindrical section of the valve body is the WR value that must be made up by the end section W_7 with length L. This difference can be stated in the following equation:

$$WR = W_1R_1 + W_2R_2 + W_3R_3 + W_4R_4 + W_5R_5 + W_6R_6 + W_7R_7.$$

The only unknown values in the above equation are W_7 and R_7 which are dependent upon the length L of the valve end section. Setting the above equation equal to W_7R_7 results in the following basic equation:

$$W_7R_7 = WR - (W_1R_1 + W_2R_2 + W_3R_3 + W_4R_4 + W_5R_5 + W_6R_6).$$

The weight of each cylindrical section of the steel G_2 valve body can be found from the following relationship:

weight of cylindrical section = (area) (length) (weight per cubic inch of steel).

Solving for the weight of each cylindrical section of the G_2 valve:

$W_1 = 0.3473\ (0.0175)\ 0.281 = 0.0017$ lb

$W_2 = 0.3834\ (0.186)\ 0.281 = 0.0200$ lb

$W_3 = 0.1963\ (0.030)\ 0.281 = 0.00165$ lb

$W_4 = 0.0491\ (0.237)\ 0.281 = 0.00327$ lb

$W_5 = 0.1199\ (0.406)\ 0.281 = 0.01368$ lb

$W_6 = 0.0767\ (0.211)\ 0.281 = 0.00455$ lb

$W_7 = 0.1199\ (L)\ 0.281 = 0.0337L$ lb.

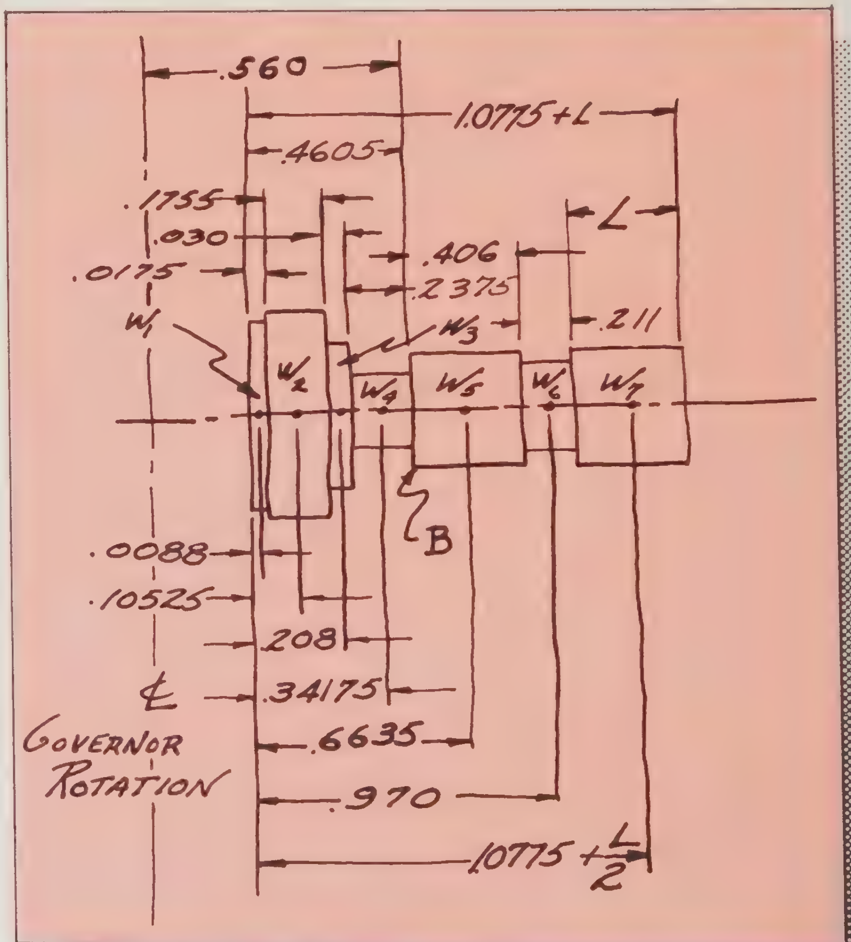


Fig. 3—Sketch of G_2 governor valve with the center of gravity of each cylindrical section of the valve designated and the distance of each center of gravity from the inner end of the valve noted.

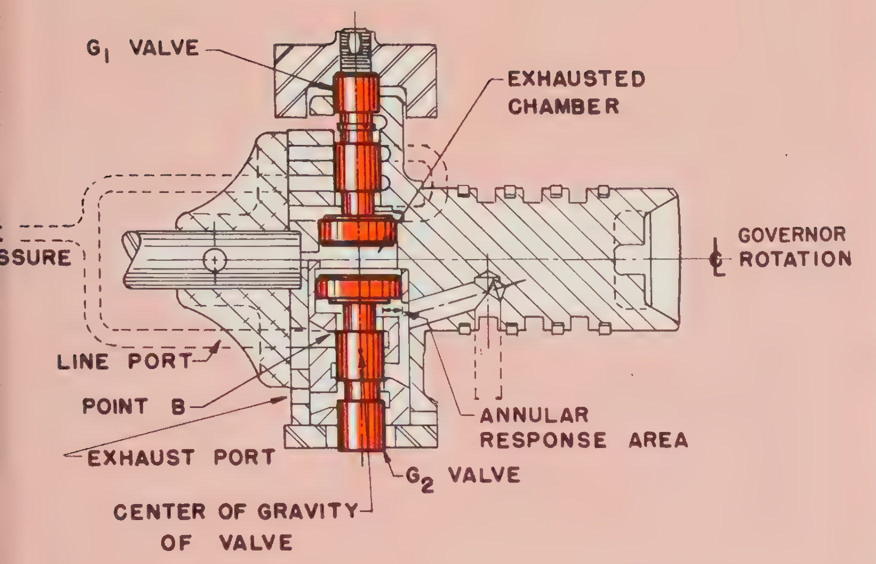


Fig. 4—Section drawing of the Hydra-Matic automatic transmission governor assembly. Point B is the only point common to both the G_2 governor valve and the valve body.

It is now necessary to calculate the radii which determine the centrifugal force produced by each cylindrical valve section. The only point that is common to both the G_2 valve and the valve body is point B (Fig. 4). Point B is 0.5600 in. from the centerline of rotation of the governor and the distance from point B to the inner end of the G_2 valve is 0.4605 in. The difference between these two values, 0.0995 in., establishes the distance from the inner end of the G_2 valve to the centerline of rotation of the governor. The radius from the center of gravity of each cylindrical section of the valve to the centerline of rotation of the governor is calculated as follows, using Fig. 3 for reference:

$$R_1 = 0.0088 + 0.0995 = 0.1083 \text{ in.}$$
$$R_2 = 0.10525 + 0.0995 = 0.20475 \text{ in.}$$
$$R_3 = 0.208 + 0.0995 = 0.3075 \text{ in.}$$
$$R_4 = 0.3417 + 0.0995 = 0.4412 \text{ in.}$$
$$R_5 = 0.6635 + 0.0995 = 0.7630 \text{ in.}$$
$$R_6 = 0.972 + 0.0995 = 1.0715 \text{ in.}$$
$$R_7 = 1.0775 + L/2 + 0.0995 = 1.1770 + L/2 \text{ in.}$$

When the values of W and R for each cylindrical section of the valve are substituted into the previously established basic equation, an expression will result in which L is the only unknown.

Substituting the values of W and R for each cylindrical section into the basic equation:

$$\begin{aligned} 0.0337\, L\, (1.1770 + L/2) &= 0.0585 - [(0.0017)\,(0.1083) \\ &+ (0.0200)\,(0.20475) \\ &+ (0.00165)\,(0.3075) \\ &+ (0.00327)\,(0.4412) \\ &+ (0.01368)\,(0.7630) \\ &+ (0.00455)\,(1.0715)]. \end{aligned}$$

Simplifying:

$$0.016825\, L^2 + 0.0396\, L = 0.0370$$

$$L^2 + 2.3536\, L - 2.1991 = 0.$$

The above expression is a quadratic equation of the form: $ax^2 + bx + c = 0$. By applying the quadratic formula, the section length L of the valve can be determined.

$$L = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$L = \frac{-2.3536 \pm \sqrt{5.5396 + 8.7964}}{2}$$

$$L = 0.7163 \text{ in.}$$

The total length, therefore, of the G_2 governor valve is equal to 1.0775 in. + 0.7163 in. or 1.7938 in.

Progress Reports from GM Locations

Artificial Weather Device Speeds Paint Failure Investigation

As a further aid in investigating the chemical reactions leading to deterioration of automotive paint finishes, the Research Laboratories Division has announced the development, in its Physics and Instrumentation Department, of a device which is capable of weathering automotive paint 20 times faster than nature. A period of from six months to a year has previously been required to wear the gloss off automotive paint when test surfaces were subjected to outdoor exposure. The new artificial weathering device reduces this time to two weeks or less.

Outdoor tests performed on paint samples at the GM Research Test Field at Miami, Florida, and at other sites pointed out that temperature and humidity conditions are the controlling factors in automotive paint failure. The tests also showed that chalking of painted surfaces—caused by decomposition of the binder in the paint—is accelerated by sunlight in the blue and ultra violet range, by oxygen, and by water. With the aid of the weathering device, research engineers are now able to duplicate the weather conditions which cause chalking of a paint and study the chemical reactions that take place during the chalking process.

Temperature conditions are duplicated in the weathering device by a 1,200-w, high pressure, mercury arc lamp. The paint test panels are clamped to a metal box which is connected to the inside periphery of the weathering unit and are directly exposed to the mercury arc lamp. Humidity conditions are duplicated by condensation of water vapor from cold water circulating through the metal box.

The experimental lacquer or enamel test panels placed in the weathering device are carefully observed while being exposed to the artificial temperature and

humidity conditions. When signs of chalking begins on any particular test panel, it is taken out immediately. In this way, it is possible to study the chemical reactions which occur during the inauguration of the chalking process. The information resulting from the chalking investigation is being used to aid in developing improved weatherproof automotive paint finishes.

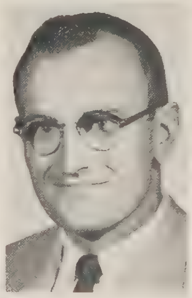
Electrical Control System Simplifies Assembly Conveyor Operation

An overhead conveyor system, complete with main line, side tracks, and switches, is being used at AC Spark Plug Division's Flint, Michigan, plant to shuttle small parts from production to assembly areas. The conveyor system is controlled by hundreds of small selector switches—a selector switch being mounted on the front of each instrument-laden carrier and being connected electrically to contact points above the carrier. The overhead conveyor line has many side switches which are opened and closed automatically by the selector switch so that the setting on the switch determines the carrier's destination.

This system departs from conventional stock-handling methods by moving stock along the ceiling rather than across the floor. In the sub-assembly areas of AC's Instrument Department, speedometers, oil gages, gas gages, ammeters, mechanical and electrical thermometers, and transmission indicators are assembled and placed on carriers. By setting a selector switch the carrier can be dispatched to any one of 47 final assembly stations where it is lowered from the rail to bench level. Switches and drop stations are equipped with adequate safety devices. Each switch is operable only when sufficient space is available on the conveyor to accommodate the carrier. Drop stations are protected while the operator has a carrier in the "down" position. The advantages of the system are: production and storage costs are reduced, existing floor space is utilized better, and safety hazards are cut.

Contributors to Nov.-Dec. 1954 Issue of

GENERAL MOTORS Engineering JOURNAL



EDWARD K. BENDA,

co-contributor of "An Automatic Load Control for Tuning-Fork Fatigue Test Equipment," is a research engineer in the Special Problems Department of the Research Laboratories Division which is located at the General Motors Technical Center.

He was originally employed by the Research Laboratories as a college graduate-in-training in 1952. In 1953 he was assigned to the Electro-Mechanical Section of the Special Problems Department in his present position. His current major project is the development of an automatic welding jig transfer mechanism using a servo control system. Previously, he was concerned with the development of a system for the automatic control of the amplitude of turbine blade vibration in a turbine blade fatigue machine. This machine is used in the evaluation of blade materials for jet engines.

Mr. Benda served in the Navy from September 1944 to July 1946 and was recalled to active duty in September 1950, specializing in electronic countermeasures. He was released in February 1952 with the rank of ensign.

He received the B.S. degree in electrical engineering from Michigan College of Mining and Technology in 1950. He is a member of Eta Kappa Nu, electrical engineering honorary society.

JOHN J. CRONIN,

contributor of "A Challenge for Today's and Tomorrow's Engineers—Making a Life in Technical Industry," is a vice president of General Motors and is the executive in charge of the Manufacturing Staff. He was appointed to this post in 1952, after more than 30 years' experience with the Fisher Body Division of GM where he rose to the position of vice president and general manager.

The Manufacturing Staff acts as an advisory body to the GM Divisions on operations in connection with manufacturing facilities and processes. In addition, this Staff coordinates the planning for the inflow of basic materials, handles the purchase, lease, and disposition of real estate for the Divisions, and assists in matters involving construction and alteration.

Mr. Cronin started his career in June 1918 in Fisher Body's Material Department, advancing by steps to the Cost Department as a cost clerk and to the Engineering Department as a production engineer. Later, he became supervisor of production standards in this same Department. In June 1934 he was appointed assistant general factory manager in charge of assembly plants and seven years later assumed the position of general factory manager. In April 1941 Mr. Cronin became director of industrial relations and in the fall of 1944 was promoted to general industrial relations director. He was named general manufacturing manager of Fisher Body Division in December 1945.

Mr. Cronin was elected a vice president of General Motors in 1948 and was named general manager of Fisher Body Division where he served until appointment to his present position.

University of Detroit granted Mr. Cronin the A.B. degree in 1915 and awarded him the honorary Doctor of Laws degree in 1951.

WILLIAM C. EDMUNDSON,

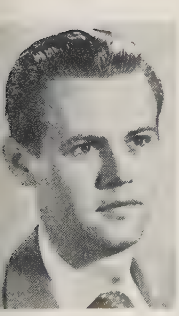
co-contributor of "Product and Production Engineers Join Forces to Make New Manufacturing Techniques Succeed," is a staff engineer in the Product Engineering Department of Delco-Remy Division, Anderson, Indiana. In this capacity, he is currently in charge of all engineering work on starting motors and generators for passenger car and farm tractor applications.

Mr. Edmundson has spent his entire engineering career with General Motors and Delco-Remy. He joined this Division in 1934 after receiving the B.S.E.E. degree from Purdue University, where he was a member of the Tau Beta Pi and Eta Kappa Nu honorary societies. Upon completion of a student-engineer training program, he was assigned to the Product Engineering Department. In 1943 he became an assistant section engineer. In 1949 he was promoted to section engineer. A short time later he assumed his present position.

Mr. Edmundson's previous major projects have included ignition equipment design and generator development work. During World War II he was concerned with developmental work on generators for bomber aircraft application. More recently, Mr. Edmundson was directly in charge of design and development of 12-volt cranking motors and generators for the new V-8 high compression engine electrical systems.

He is a member of the Society of Automotive Engineers and serves on the Society's V-Belt Subcommittee.

WARREN E. FINKEN,



contributor of this issue's "Notes About Inventions and Inventors," is a patent attorney in the General Motors Patent Section. He is assigned to the Dayton, Ohio, office of the Patent Section, one of three principal locations of patent activities in General Motors. Other offices are at Washington, D. C., and at the GM Central Office in Detroit.

The Dayton office deals primarily with matters relating to patents, copyrights, trademarks, and licensing agreements affecting a number of GM Divisions including those located in the Dayton area. The Dayton Divisions are: Aeroproducts Operations of Allison Division, Delco Products Division, Frigidaire Division, Inland Manufacturing Division, and Moraine Products Division. Mr. Finken's work is concerned with patents in the fields of windshield wipers, aircraft propellers, and aircraft actuators.

Mr. Finken was employed by General Motors in 1948, immediately following his graduation from the University of Wisconsin where he received the B.S.M.E. degree. He began as a patent searcher in the Washington office of the Patent Section and concurrently with his work there he attended George Washington University, receiving the L.L.B. degree in 1951. Shortly afterward, he was made patent attorney and was transferred to the Dayton office to take up his present duties.

Mr. Finken is a registered patent attorney and a member of the District of Columbia bar. He is a member of the honorary societies of Pi Tau Sigma and Phi Beta Tau and a member of the American Patent Law Association and the Dayton Patent Law Association. He served in the U.S. Navy from 1945 to 1946 as an aircraft electronics technician with the rank of petty officer 3rd class.

WILLIAM A. FLETCHER,

co-contributor of "Product and Production Engineers Join Forces to Make New Manufacturing Techniques Succeed," is chief process engineer in the Process Department of Delco-Remy Division, Anderson, Indiana. In this position, he is responsible for the development of new and improved product manufacturing methods.

Mr. Fletcher originally joined General Motors in 1926 as a machinist in Chevrolet Motor Division's Flint, Michigan, plant which sponsored him as a cooperative student at General Motors Institute. He was graduated in 1930 and then transferred to Delco-Remy. There, his first assignment was in the Process Laboratory and in 1938 he was promoted to process project engineer. He assumed his present position in 1951.

Some of Mr. Fletcher's previous major projects have included the development of press application to the cold-forming of automotive electrical parts, application of resistance welding techniques to automotive tubing, and engineering design work on servomechanisms. In summary, his work has encompassed almost all phases of process development work.

Twelve patents have been granted as a result of Mr. Fletcher's work in the fields of molding, welding, servomechanisms, presses, and specialized manufacturing machinery. His technical affiliations include membership in the Society of Automotive Engineers, which has published one of his previous technical papers.

RAYMOND A. GALLANT,

co-contributor of "An Automatic Load Control for Tuning-Fork Fatigue Test Equipment," serves as a research engineer in the Special Problems Department of the Research Laboratories Division, located at the General Motors Technical Center.

He joined the Division as a college graduate-in-training in 1950. In 1951 he was assigned to the Vibration and Stress Analysis Section of the Special Problems Department as a junior engineer and in 1953 became a research engineer. Currently, he has as a major project the development of a hydraulic cranking motor for Diesel equipment. His previous major projects have included general fatigue studies and work with engine combustion roughness.

Mr. Gallant earned the B.M.E. degree from Rensselaer Polytechnic Institute in 1950 and the M.S. degree in engineering mechanics from the University of Michigan in 1954. He is a member of Tau Beta Pi, Sigma Xi, Pi Tau Sigma, and Alpha Psi Omega honorary societies.

He served as a naval aviator in the U.S. Navy Reserve from 1942 to 1946. Presently, he is a lieutenant in the Navy Reserve and serves as executive officer of a week-end squadron at the Naval Air Station at Grosse Ile, Michigan.

He is a member of the Society for Experimental Stress Analysis. The paper appearing in this issue had its origin in a paper which he presented to this group.

CHARLES W. GARDNER,

contributor of "Factors Involved in the Use of Air for Precision Measurement," has devoted the major portion of his technical interest to metal cleaning, painting, and plating operations and, during recent years, to the development of special-purpose gages. He is now senior project engineer-in-charge of gaging equipment and painting in the Engineering Department of the Process Development Section, located at the GM Technical Center.

Mr. Gardner, upon receiving the B.S. degree in chemical engineering from Michigan State College in 1941, became a chemical engineer in the Chemical Process Engineering Department of Yellow Truck and Coach Manufacturing Company, which is now GMC Truck and Coach Division. One of his first assignments was to find a safe way to de-fume gasoline tanks. The chlorinated solvent method adopted remains in use to the present time. During World War II his efforts were centered on cleaning and preparation of metals for a variety of military vehicles, including sheet metal for the amphibious DUKW. He also contributed to the adoption of Bonderizing aluminum.

During the post-war period his work on the design of painting equipment was intensified and one of his last tasks at GMC was the design of a sheet metal paint shop. He was transferred to the Process Development Section in July 1949 as a project engineer and his first major project—one which remains active to date—had to do with electronic paint spray methods with particular emphasis on their practical application to production lines. His promotion to senior project engineer came in December 1950, after which his interests expanded in the area of his current paper.

While in Pontiac, with GMC Truck and Coach, he became one of the early members of the GM Industrial Waste Control Committee and of the GM Paint Committee.

GALEN F. RICHARDS,

contributor of "Simplifying Problems of Material Identification Through the Development of a Coded Stock Numbering System," is a senior cost estimator in the Estimating Section, Factory Accounting Department, at Inland Manufacturing Division, Dayton, Ohio.

Mr. Richards' interest in material control activities dates back to his original employment at Inland in 1945. He joined the Division as a visual inspector in the Inspection Department and was enrolled as an Inland-sponsored cooperative student in the industrial engineering program at General Motors Institute, Flint, Michigan. His schooling was interrupted by a year's service with the U. S. Army from 1946 to 1947, during which period he served as an administrative non-commissioned officer, attaining the rank of staff sergeant.

Returning to General Motors, he completed his work at General Motors Institute and was awarded the Bachelor of Industrial Engineering degree in 1952. As required for this degree, he completed his Fifth Year Project Study Report and wrote the thesis "The Development of a Coded Stock Numbering System." His manuscript appearing in this issue is based on the study made in connection with this report. The purpose of the study was to develop a new stock or indirect material numbering system to indicate the classification and kind of material, and to develop a procedure for putting the system into operation at Inland. The products manufactured by this Division are in the fields of rubber, plastics, friction material, and metal, and include steering wheels, decorative body parts for automobiles, self-sealing windshield strips, brake hose and lining, clutches, and ice trays for domestic refrigerators.

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

Mr. Richards was made junior cost estimator in the Estimating Section of the Factory Accounting Department in December 1951 and was promoted to his present position in 1953.

GEORGE R. SMITH,

who prepared the problem "Determine the Length of the Governor Valve in the Hydra-Matic Automatic Transmission" and the solution appearing in this issue, is assistant engineer-in-charge of the Transmission Development Group, General Motors Engineering Staff, GM Technical Center. In this capacity, he has supervision of the testing and build-up of future automatic transmissions.

Mr. Smith joined General Motors in 1933, when he was employed by Buick Motor Division, Flint, Michigan. Under this Division's sponsorship he attended General Motors Institute, from which he graduated in 1937. While attending G.M.I., Mr. Smith fulfilled various work assignments at Buick, including work in the Tool Engineering Department. During his last two years at the Institute he served as an instructor of mathematics and engineering drawing. After graduating from G.M.I., Mr. Smith was concerned with final inspection work on the semi-automatic transmission being produced by Buick at that time. In addition to his work at Buick, he also continued his instructor's duties at G.M.I. on a part-time basis.

Mr. Smith transferred from Buick to the Detroit Transmission Division in 1939, where he worked as a designer. The following year he joined the Transmission Development Group of the GM Engineering Staff as a designer and in 1945 was promoted to project engineer. He assumed his present position in 1952.

Some of Mr. Smith's previous projects include developmental work on hydraulic transmissions for military and commercial applications and developmental work on the torque-converter-type of automatic transmission.

Mr. Smith's technical affiliations include membership in the Society of Automotive Engineers.

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June-July 1953 to November-December 1954

Published by GENERAL MOTORS CORPORATION

Detroit 2, Michigan

General Motors Engineering Journal

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(CP) Classroom problem
(Ed) Editorial (always appears on unnumbered inside front cover)
(I) Inventor
(P) Portrait

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GENERAL MOTORS

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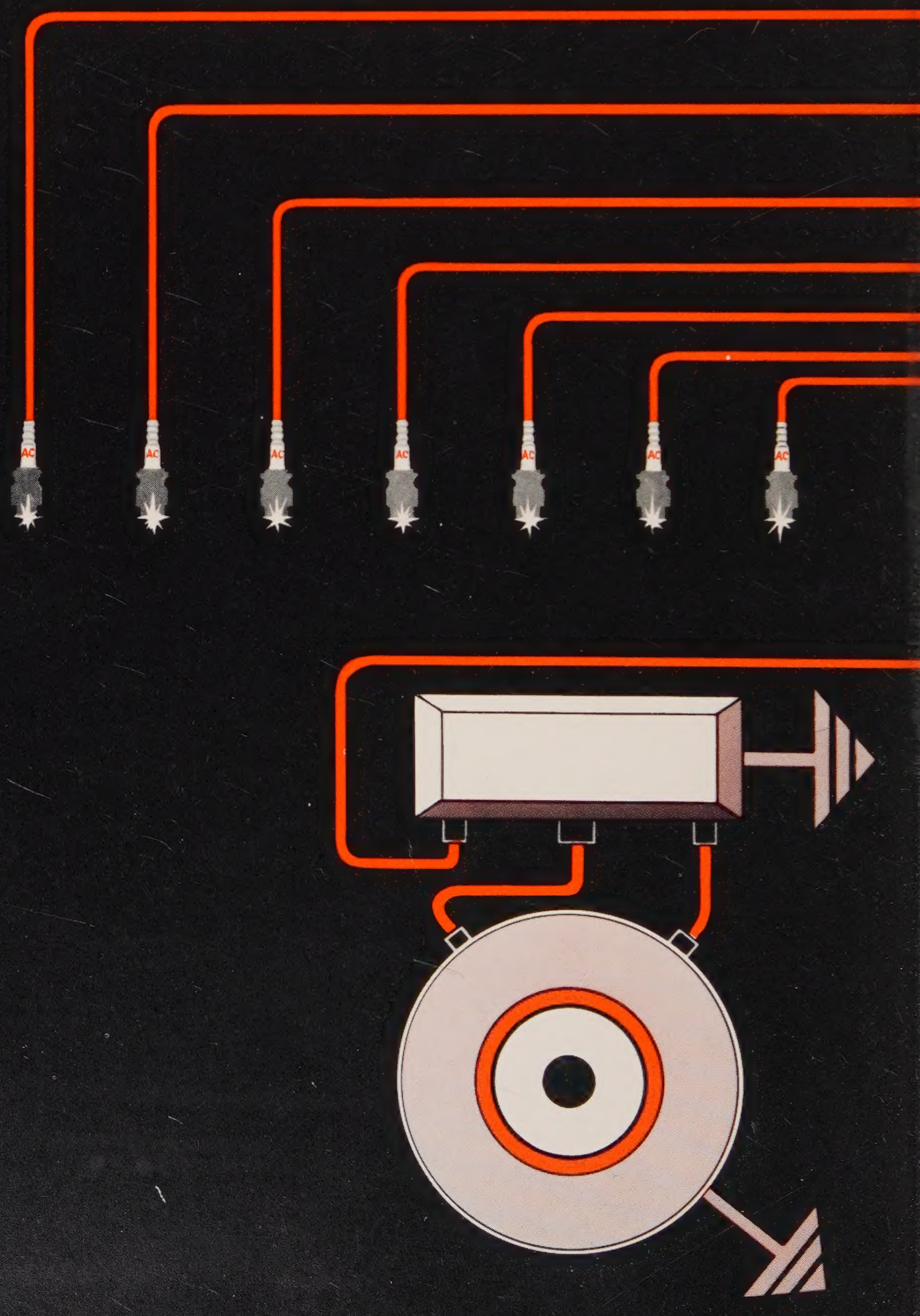

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